



SLAB REPLACEMENT GUIDELINES



STATE OF CALIFORNIA
DEPARTMENT of TRANSPORTATION

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DISCLAIMER

These *Slab Replacement Guidelines* are intended for use by Caltrans' personnel. Engineers and agencies outside of Caltrans may use these guidelines at their own discretion. Caltrans is not responsible for any work performed by non-Caltrans personnel using this guide.

Caltrans intends these guidelines as a resource for all personnel engaged in slab replacements. These guidelines reflect the recommended practice and procedures for design and construction of slab replacements. However, these guidelines are not contract documents. They impose no obligations or requirements on contractors. Resident engineers and other Caltrans personnel who administer Caltrans contracts must never attempt to use these guidelines as a substitute or supplement to the specifications and other contract requirements.

ABSTRACT

These *Slab Replacement Guidelines* were developed by the Office of the Rigid Pavement Materials and Structural Concrete of the California Department of Transportation (Caltrans). They include several key factors that help reduce the time necessary to accomplish slab replacement and improve the quality of the repaired concrete pavement, including the proper selection of the slab removal boundaries and concrete material. Also included are the recommended procedures for saw cutting, slab removal, subgrade and base preparation, concrete placing and curing, sampling and testing procedures, grinding and joint sealing, and opening to traffic criteria. A practical checklist that provides a quick summary of the entire process is also provided in Appendix A.

These slab replacement guidelines have been reviewed and endorsed by the Western States Chapter of the American Concrete Pavement Association.

Questions on these guidelines can be directed to Materials Engineering and Testing Services (METS) Office of Rigid Pavement Materials and Structural Concrete: (916) 227-7281.

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CHAPTER 1 INTRODUCTION



1938 Highway 33
near Pulgas Road



1958
Santa Ana Freeway



Paving in the 1970's

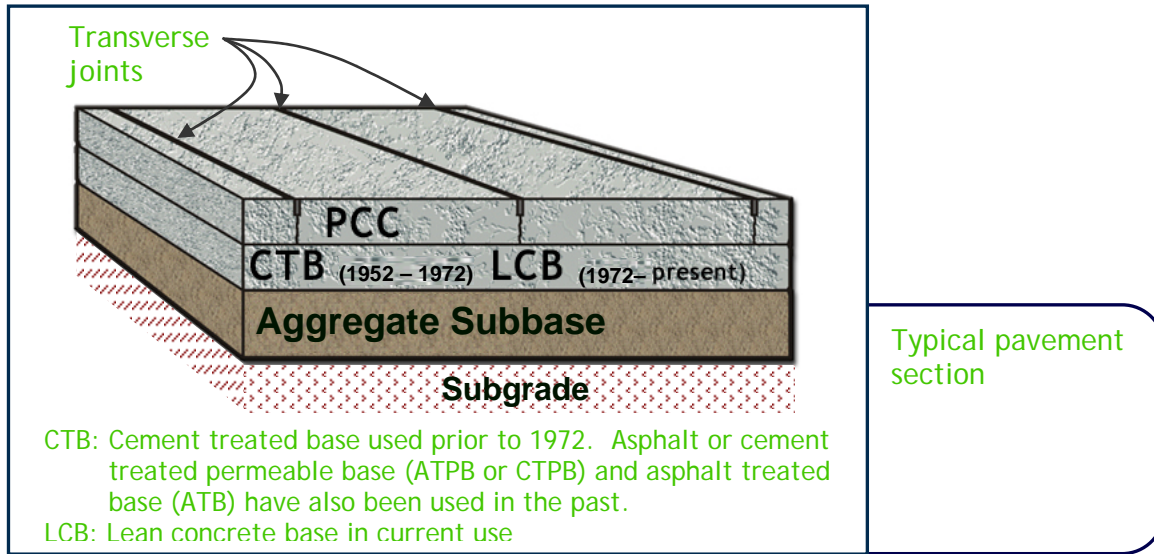
HISTORICAL PREFACE

Most of Caltrans' rigid pavements were built between 1950 and 1970, and they were designed to last 20 years. These pavements have greatly exceeded that design life, and many now need to be rehabilitated or replaced.

Due to the high capacity demand for most of California's urban freeways, Caltrans is often restricted to very short construction windows for pavement rehabilitation. Often the available time for lane closure may be as short as 5 hours and nighttime construction is required, depending on the direction of peak traffic and the day of the week.

Meeting these needs creates difficult challenges for Caltrans' staff and contractors. Many concrete pavements are restored to an acceptable performance level using slab or slab and base repairs. The effectiveness of this repair strategy depends on proper evaluation of the extent and severity of the slab distresses, as well as the condition of the underlying pavement layers.

TYPICAL PAVEMENT SECTION



The most appropriate slab repair must be determined based on the condition of the entire pavement section to be repaired, including the need to remove and replace the existing base. Repair type selection can significantly influence the number of slabs replaced during each shift, as well as the duration and cost of the project. For example, selecting a slab and treated base repair instead of a slab repair when the treated base is in good condition will result in an unnecessary increase in construction time and material costs. Likewise, if only a slab repair is performed when the treated base or underlying subgrade has significant deterioration, the repair may not perform well and it will require additional time and money to improve the repair area to an acceptable level.

It is very challenging to identify the appropriate slab repair properly on a case-by-case basis. **The selection of the proper repair type will save the project time and money by minimizing unexpected or unnecessary repairs.**

Another challenge faced by Caltrans and the contractors is good construction practices. For slab replacements to maintain good performance over time, **the use of proper construction techniques is extremely important.**

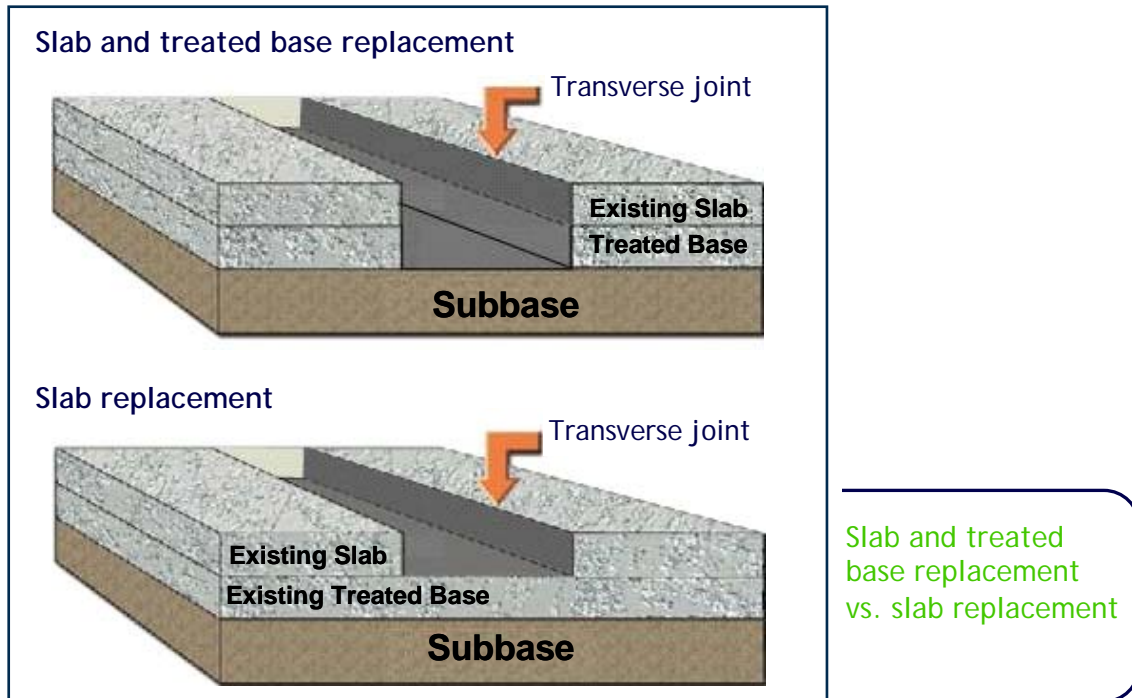
TYPICAL PAVEMENT SECTION

All standard Caltrans rigid pavements constructed prior to 1993 are plain jointed portland cement concrete (PCC). This means that the slabs are not reinforced with steel rebar or welded wire fabric. They are also constructed without any load transfer devices, such as dowels at the transverse joints. However, prior to 1940, jointed plane concrete pavement (JPCP) routinely included dowels at the transverse joints. Older pavement may contain dowel bars as a result of recent retrofitting. Some non-standard design features, such as continuous reinforcement, have been used in test sections, but only in a few isolated locations.

Cement treated base (CTB) became the standard in 1952, although CTB is no longer used under PCC pavements. Lean concrete base (LCB) replaced CTB as the standard base in 1975. In 1983, Caltrans adopted treated permeable base as an allowable base type under JPCP. Asphalt treated base was also used in the past.

In 1993, tied PCC shoulders, tied longitudinal joints, and sealed joints were implemented as a standard for rigid pavements. The Caltrans standard also includes doweled transverse joints as an option. The details of the standard PCC pavement designs are given in Caltrans standard plans (see Appendix E for reference).

SLAB REPLACEMENT



SLAB REPLACEMENT

For the purposes of these guidelines, a slab replacement is defined as a single slab to be replaced in kind. In general, replacement of multiple slabs totaling 30 m or longer is considered lane replacement.

Slab replacement can improve pavement rideability and restore structural integrity while extending service life. Slab replacement can be defined as a slab and treated base or slab repair. Slab and treated base repair consists of removing the concrete pavement, including the treated base, and replacing both layers with rapid strength concrete (RSC) materials, separated by a bond breaker. Slab repair is the removal and replacement of the concrete pavement surface.

Partial-depth repair is the removal and replacement of the concrete pavement surface to not more than $1/3$ of the depth of the slab. Partial-depth repairs are appropriate only for spall repairs at pavement joints. Slab replacement should be used if the spalling extends more than $1/3$ of the depth of the slab or if spalled areas at a joint total 1 m^2 or more.

The treated base and RSC pavement shall be poured separately as long as adequate time is available for the pavement layers to cure properly. In a very short construction window (2-4 hours of cure time), replace the existing treated base with RSC. After placing the RSC for the base layer, a bond breaker is placed on the surface of the replacement base after the base has hardened sufficiently (e.g., hard enough to walk on).

Load transfer should be provided at transverse joints as specified in project plans. Typically, this is accomplished by drilling holes into the existing PCC and securing dowels in the drilled holes with epoxy. Optionally, the dowel bars may be retrofitted.

Repairs and rehabilitation efforts can include jobs as small as a single failed pavement slab panel or as large as the replacement of multiple panels. In general, full panel replacements should be used, unless the slab to be replaced is very long (e.g., 6 m or longer). **The absolute minimum size of a slab replacement should be the full slab width, 3.6 m wide by 2 m long.**

KEYS TO SUCCESS

KEYS TO SUCCESS

Several key factors help reduce the time necessary to accomplish slab replacement and improve the quality of the repaired concrete pavement. Many aspects of a project should be considered, including the following:

DESIGN

- Thorough review of project – prior to advertising, the project engineer should review the project to verify pavement condition
- Proper selection of slab removal boundaries on the plans
- Concrete material selection and approval
- Replacing existing tie bars
- Grinding and joint sealing
- Opening-to-traffic criteria

INSPECTION

- Conformance with the contract specifications and plans
- Proper selection of slab removal in the field or based on initial survey
- Procedure for saw cutting and concrete removal
- Preparation and compaction of subbase material
- Dowel installation techniques
- Concrete placing and curing provisions
- Sampling and testing procedures
- Grinding and joint sealing
- Opening-to-traffic criteria

CONTRACTOR

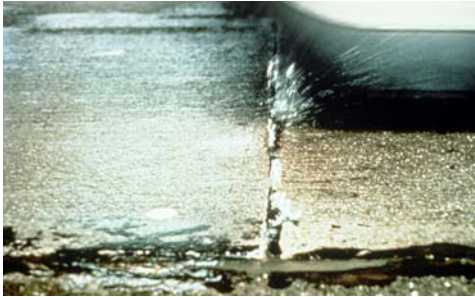
- Concrete material selection and approval
- Procedure for saw cutting and concrete removal
- Preparation and compaction of subbase material
- Dowel installation techniques
- Concrete placing and curing
- Grinding and joint sealing
- Opening-to-traffic criteria

NOTE TO DESIGNERS:

During short construction windows, the contractor will need to replace the slab and allow it to cure to reach strength. Do not specify the drill-and-bond method of dowel placement if the construction window is less than 8 hours. Dowels may be retrofitted on projects with a short construction window. Typically, contractors can place 20 to 26 replacement slabs within an 8-hour construction window.

Any use of dowel bars at repair joints should be well documented to avoid costly change orders if the project is later selected for dowel bar retrofitting.

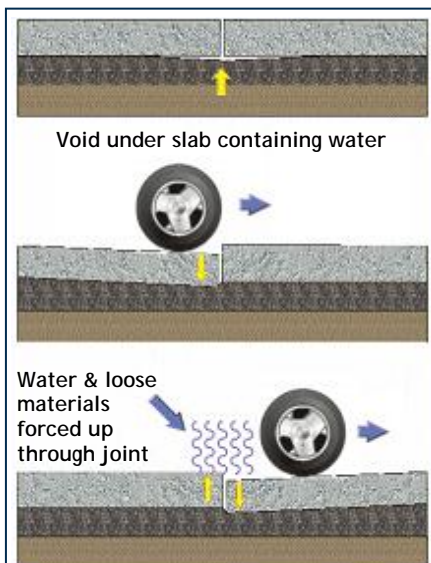
CHAPTER 2 PROJECT EVALUATION



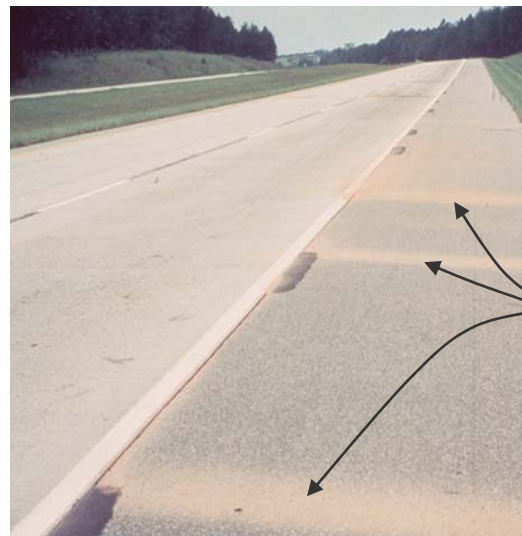
Pumping in action



Loss of shoulder material due to pumping



Pumping schematic



Pumping of loose pavement fines onto the highway shoulder

SLAB REPLACEMENT CONSIDERATION

In planning a slab replacement project, it is important to consider the pavement age, pavement condition, and traffic levels. Not all projects are good candidates for slab replacements (see p.18). For example, slab replacement is not an effective rehabilitation strategy for structural deficiency and for problems in concrete material, base, or subgrade. Such problems require a structural overlay or reconstruction. A relatively new pavement (<10 years old) exhibiting extensive cracking and a pavement that is rapidly developing new cracks are some of the signs of structural deficiency. Cost is also a factor, and slab replacement may not be economical for badly cracked pavements (e.g., 3rd stage cracking in more than 10% of slabs).

PAVEMENT CONDITION SURVEYS

Caltrans conducts pavement condition surveys annually. The survey data can be obtained from the District Maintenance Engineer. Also the Office of Pavement Rehabilitation at Translab can be contacted to obtain falling weight deflectometer (FWD) readings or drill cores. The FWD data can be used to determine load transfer efficiency (LTE, see page 13).

The data from annual surveys can be used to determine the extent of damage to slabs and ride quality. The results of the survey should be used as a trigger for slab replacement. Some of the key distresses are defined in this chapter.

PUMPING

PUMPING

Pumping is the ejection of loose materials carried by water from under the pavement through cracks and joints when impacted by traffic.

Causes:

Four conditions must coexist for pumping to occur: frequent heavy axle loads, poor joint LTE, erodible base and/or wet-fine subgrade, and the presence of excess water under the pavement.

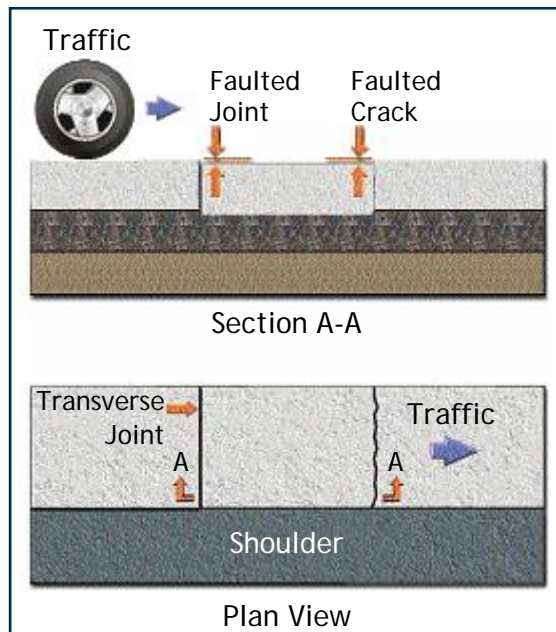
- Sealing the longitudinal and transverse joints reduces water infiltration and keeps the incompressibles out.
- Pumping becomes a serious problem when the displaced material results in loss of support, especially at the corner, where larger deflections and stresses may result in corner breaks.

- Pumping can also cause transverse cracking, spalling of the joints, and faulting, and it may contribute to longitudinal cracking.
- Fines from pumping and erosion of the base and subgrade can be seen along shoulders, especially after a rainstorm, as shown on page 5.

Sunken shoulders and loss of fine material are an indication of potential problems. If pumping has not caused significant deterioration, a possible maintenance remedy is to insert grout or polyurethane foam into the voids to reduce slab movement and deter deterioration. Grout pumping is typically used by maintenance personnel as a temporary measure and should not be used on construction contracts. However, grouting may be required for innovative pavement construction, such as precast PCC slab construction. Any use of grouting in such applications should be in compliance with the Caltrans specifications for the application.

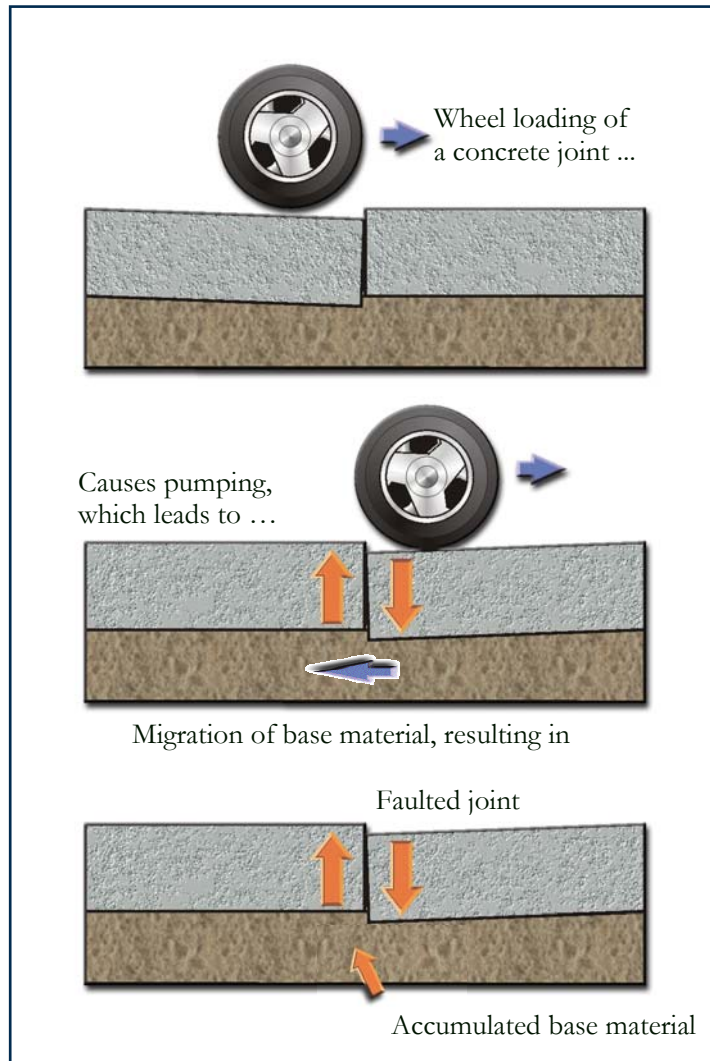


Faulted joints



Faulting schematic

FAULTING



Faulting mechanism

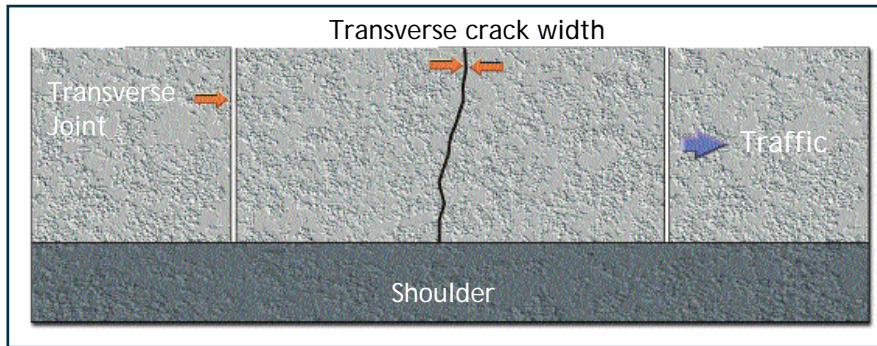
FAULTING

Faulting is a difference in elevation between slabs at joints or cracks.

Causes:

- Faulting is caused by a combination of heavy axle loads, poor joint or crack load transfer efficiency, erodible material in the layers beneath the concrete slab, and the presence of free water beneath the pavement.
- Temperature and moisture gradients can curl the slab corners upward, resulting in increased potential for pumping and faulting.
- The hydraulic action drives the fines beneath the pavement slab in the direction opposite the direction of traffic. Over time, this results in a buildup of fines under the approach side of the joint. The amount of buildup coincides with the amount of faulting (step-off) on the pavement surface.

TRANSVERSE CRACKS



Transverse crack schematic



Transverse cracking

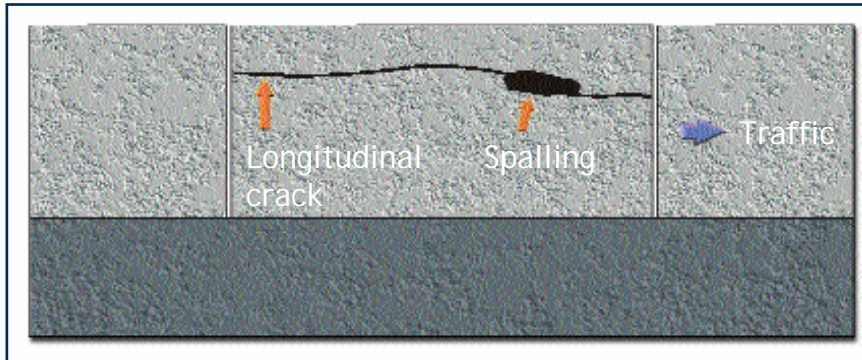
TRANSVERSE CRACKS

Transverse cracks cross the slab in a direction nearly perpendicular to the pavement centerline and the direction of traffic.

Causes:

- Typically, new concrete slabs crack when tensile stresses within the slab exceed the slab's tensile strength. Early-age cracking may occur from a combination of restraining forces due to temperature changes, shrinkage, thermal curling, and moisture warping, combined with traffic loads imposed on the concrete before it has gained sufficient strength. This type of cracking can be controlled by sawing the pavement to create weakened-plane joints at appropriate intervals. Uncontrolled (volunteer) transverse cracks typically result from improper joint sawing (shallow sawed depth or late sawing).
- Transverse cracks that occur in the years following construction are primarily the result of fatigue of the concrete slab caused by repeated heavy axle loads and temperature curling. The cracks develop when the accumulated fatigue damage approaches or exceeds the fatigue life of the PCC.
- Shorter panel lengths used today reduce the potential for fatigue-related transverse cracking. Excessive panel lengths (e.g., 6 m) lead to excessive curling and warping stresses, which often lead to premature mid-panel cracking. Refer to the Caltrans Standard Plans for the current transverse joint spacing.

LONGITUDINAL CRACKS



Longitudinal crack schematic



Longitudinal cracking

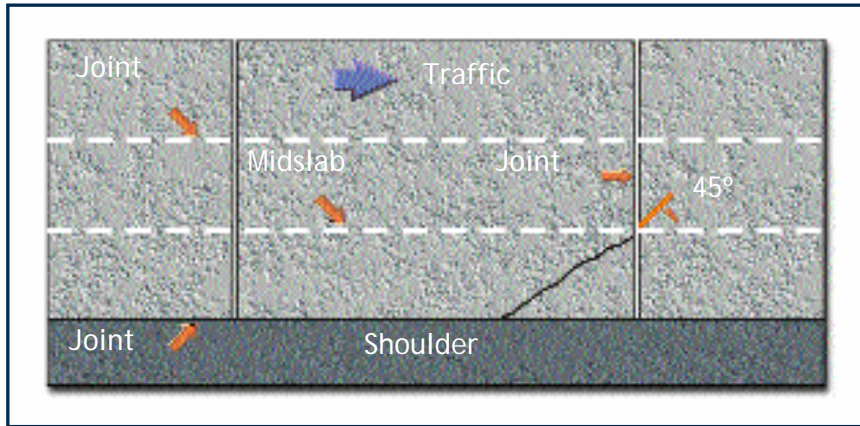
LONGITUDINAL CRACKS

Longitudinal cracks run parallel to the edge of the slab and in the direction of traffic.

Causes:

- Early longitudinal cracks can be caused by inadequate saw-cut depth or late sawing of longitudinal joints. Unless the joints form properly, the risk of longitudinal cracking is very high due to the restraining forces from shrinkage or temperature changes and stresses from slab curling and warping. Early cracking can also result from opening the pavement to traffic before the concrete has achieved adequate strength.
- Longitudinal cracking occurring late in the pavement's life may be caused by a combination of upward slab curling (temperature and moisture gradients) and heavy repeated axle loadings.

CORNER BREAKS



Corner breaks schematic



Corner breaks

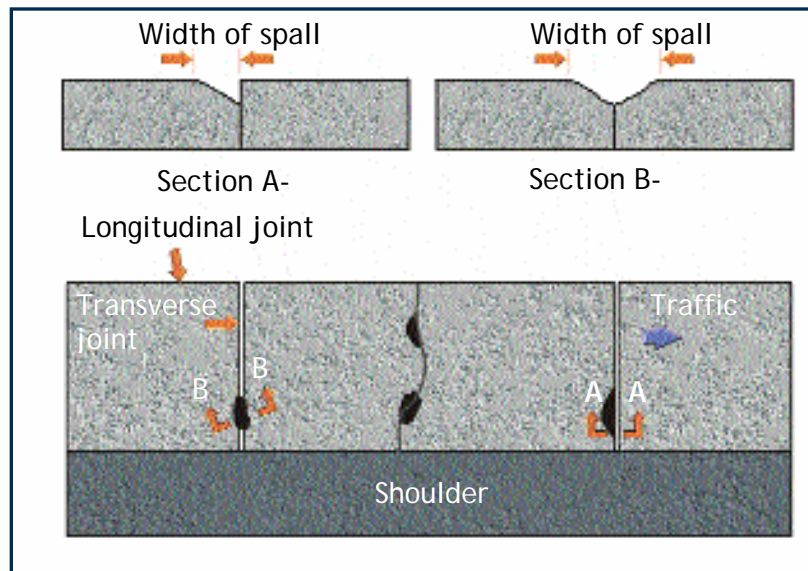
CORNER BREAKS

A corner break is a crack that intersects a transverse joint and the pavement edge at a distance of about 2 m or less on each side from the corner of the slab and is over 0.5 m long.

Causes:

- Corner breaks are caused by heavy repeated axle loadings on upward curled slab corners due to temperature and moisture gradients, and lack of adequate load transfer.
- Loss of slab support (voids) due to pumping.

JOINT SPALLING



Joint spalling schematic



High-severity joint spalling

JOINT SPALLING

Joint spalling can occur at both the transverse and longitudinal joints. Medium- and high-severity spalling require full-depth repairs, unless the deterioration is limited to the upper 1/3 of the slab, in which case partial-depth spall repairs may be feasible. On a typical joint, coring can help determine the general extent of the subsurface deterioration beneath the joint.

Causes:

- Spalling is caused by the build-up of incompressible materials in the joints, which causes large stresses when the slab expands. As the face of

the joint or crack spalls, it deposits more incompressibles, causing further deterioration.

- Weak areas caused by inadequate consolidation of the concrete near joints provide a starting point for spalling to occur.
- Some joint spalling may be the result of concrete durability distresses, such as reactive aggregate.

While joint spalling is not the focus of this document, it may be appropriate to address medium- and high-severity spalls during slab replacements.

STAGES OF SLAB DETERIORATION



First-stage cracking



Third-stage cracking

ADDITIONAL PAVEMENT DISTRESS FACTORS

Other factors that may contribute to joint deterioration are:

- Poor design or construction practices that create locally weak areas within the slab
- Poor joint sealant maintenance
- Improper installation of joint sealant

STAGES OF SLAB DETERIORATION

There are three distinct stages of slab deterioration, according to the Caltrans Highway Design Manual:

- **First-stage cracking:** Non-intersecting transverse, longitudinal, or diagonal cracks in a slab that divide the slab into two or three large pieces. This does not include corner breaks.

- **Third-stage cracking:** Cracking of the slab into three or more pieces with interconnected cracks developing between cracks or joints.

Note:

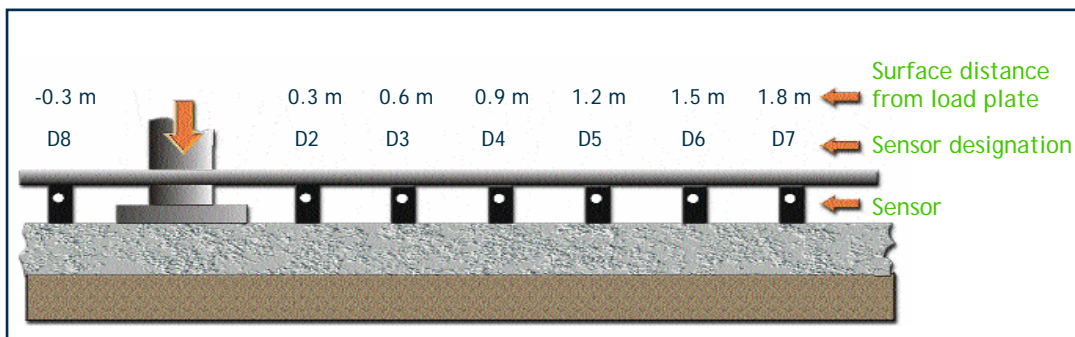
Stage 1 and Stage 3 cracking cannot coexist within the same slab; however, corner breaks may coexist with both Stage 1 and Stage 3 cracking.

Stage 2 cracking is not considered for this type of evaluation.

NONDESTRUCTIVE TESTING



Falling Weight Deflectometer (FWD)



Typical FWD load plate & sensor spacing

TYPICAL PAVEMENT INSPECTION TECHNIQUES

Various techniques can be used to assess pavement condition. Common approaches include conducting falling weight deflectometer (FWD) testing, drainage survey, and coring.

NONDESTRUCTIVE DEFLECTION TESTING

A number of nondestructive pavement testing devices are currently in use, but the FWD is the most widely accepted in the pavement engineering field. The FWD consists of an impulse loading device that applies a load to the pavement surface by dropping a weight onto a spring buffer connected to a load plate of known dimensions. By varying the falling weight mass and the drop height, the magnitude of the applied load can be changed. The resulting pavement deflection is measured by seismic deflection transducers. One transducer is located at the center of the loading plate, and the remaining sensors are commonly spaced at 300-mm intervals away from the load plate.

By collecting deflection measurements at several offsets from the load plate, the deflection profile (or basin) can be determined. In general, weak pavements have high deflections that are confined to a small area, and stiff (strong) pavements have small deflections that are distributed over a much wider area. By analyzing the magnitude and shape of the deflection basin at the slab center, the strength of the in-place pavement and subgrade materials can be estimated. In addition, the load transfer efficiency at joints and cracks, as well as the presence of voids at corners, can be evaluated quickly.

Nondestructive testing (NDT) provides information about a pavement's overall structural capacity, and it can pinpoint areas of weakness. NDT alone cannot, however, completely identify which pavement component is responsible for weaknesses, or whether moisture-related problems exist. A pavement drainage survey and limited coring may also be required.

PAVEMENT DRAINAGE ANALYSIS



Pumping of
pavement
materials

Fines shown on shoulder of base
material pumped to surface indicates
possible voids under pavement



Properly
functioning
pavement
edge drain

PAVEMENT DRAINAGE ANALYSIS

Excess water in the pavement structure is often a significant contributor to poor pavement performance, even in dry climates. Moisture-related or moisture-accelerated rigid pavement distresses include pumping, faulting, and cracking, as well as PCC material problems such as alkali-silica reactivity (ASR). Water can enter the pavement structure from the top (through joints and cracks on the pavement surface), laterally (through the natural soils), and from the bottom (capillary action from the underlying water table).

The drainage survey should provide answers to the following questions:

- Are the joint sealants in satisfactory condition?
- Are the ditchlines properly graded and clear of debris or vegetation?
- Is there standing water or signs of standing water in the ditchlines?
- After a rainstorm, is there water standing in the joints or cracks?

- Is there evidence of pumping, or do small settlements exist in the AC shoulders at joints (blow-holes)?
- Is there water standing at the outer edge of the shoulder, or is there evidence that water may pond on the shoulder, as shown by stains or fine material accumulation (see photos on page 15)?

If subsurface drainage is present:

- Are the outlets clear of debris and set at the proper elevation above the ditch line?

Identifying drainage problems is important for ensuring good long-term performance of rehabilitated rigid pavements. Certain problems, such as clogged drainage fabric, are not always correctable, and the presence of significant drainage problems may limit the feasibility of pavement rehabilitation through restoration methods.

PAVEMENT DRAINAGE ANALYSIS (CONTINUED)



Erosion & settlement of the shoulder material



Distressed PCC patch due to construction of the patch wider than the paving lane



Edge form placed after removing 0.3 m of deteriorated shoulder

There may be other more cost-effective means, other than slab replacement, to address problems that are either caused or aggravated by poor drainage.

- Pumping and faulting may be addressed effectively through the addition of retrofitted dowel bars and diamond grinding.
- Pavement drains may be repaired cost-effectively, depending on the drainage rehabilitation required. Use engineering judgment during the pavement drainage survey.

If the drainage system collapses during pavement removal:

- Place a form at the edge of the concrete pavement lane to allow a full slab width replacement to occur.

- Replace the edgedrain, in kind, and backfill with AC.
- Never construct a replacement slab wider than the paving lane.

NOTE TO DESIGNERS:

When the shoulder is severely distressed or settled, be sure to include detail and funding to remove 0.3 m of shoulder and place a form for the edge of pavement. The form will also be used to set a smooth grade. The gap must be backfilled with AC to match the adjacent shoulder.

CORING



Core drilling



Coring to investigate the causes of pavement distress

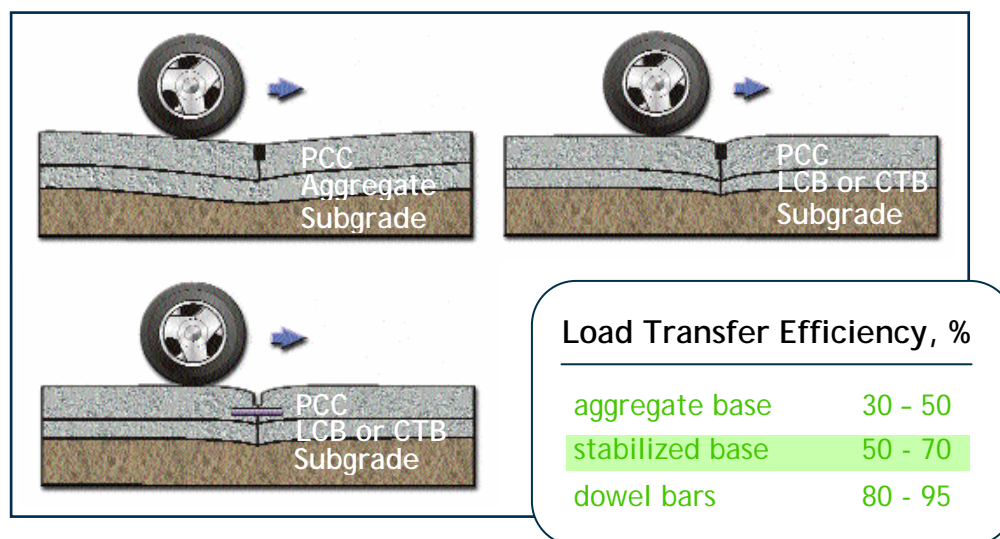


Core with backer rod and aggregate interlock

CORING

Limited coring may be needed to determine the extent and severity of distress beneath the pavement surface. Coring should only be used on a limited basis because it is time-consuming and causes additional lane closures. Work with your District Materials Engineer (DME) to obtain the cores. Cores will give you information about the condition and thickness of the existing concrete pavement, treated base layer, and subbase, which may indicate whether the base will need to be removed and replaced with the slab.

LOAD TRANSFER



LOAD TRANSFER

Caltrans' concrete pavements typically rely on aggregate interlock and the treated base course for load transfer. The coarse aggregate in the PCC at the slab joint faces interlock to help transfer wheel loads from one slab to the next. The bottom figure on the opposite page shows a good example of aggregate interlock. Over time, the exposed surface of coarse aggregate may become worn due to repeated loadings and weathering, resulting in a smoother texture and a lower load transfer capacity. This reduction in load transfer capacity leads to increased joint movements and an increase in pavement distresses.

Aggregate interlock may provide adequate load transfer throughout the design life during warm weather, but the load transfer can vary considerably throughout the year. In fact, Caltrans has observed significant differences in the load transfer between early morning and afternoon. As the joint opens due to temperature variations, aggregate interlock is lost and load transfer is greatly reduced. Load transfer also decreases over time due to friction abrasion of the joint face.

Depending on the size and type of aggregate, an opening as small as 0.25 mm can cause a significant reduction of the LTE. Stabilized base and dowel bars improve LTE and reduce the impact of temperature and abrasion. FWD testing is important to determine the LTE of joints and cracks within the project, especially during cooler weather (<25°C).

Typically, pavement sections with deflection load transfer values less than 70 percent do not perform adequately. Those pavements may show signs of pumping, faulting, corner breaks, and spalling and may require slab replacement. Joints and cracks with LTE greater than 70 percent may provide an acceptable serviceability level for many years. Joints or cracks with poor LTE and no other associated distresses may benefit from dowel bar retrofit, which can be a more cost-effective repair.

LOAD TRANSFER DESIGN

Dowel bars are highly effective in providing load transfer across joints or cracks. The recommended dowel bars are 460 mm long and 38 mm in diameter. New construction requires 12 bars, spaced 300 mm on center along the transverse joint. Slab replacements require 3 dowel bars spaced 300 mm on center in each wheel track for non-truck lanes and 4 bars spaced 300 mm on center in each wheel track for truck lanes. Since lane striping is subject to change, Caltrans has allowed for nine bars to be spaced evenly across the transverse joint; however, the design that concentrates the bars in the wheel tracks with a bar spacing of 300 mm is highly recommended. If the location of lane striping is uncertain, use 12 bars at 300 mm spacing. For new transverse joints located 2.3 m or less from the existing slab transverse joint, tie bars may be installed at 600 mm on center along the new construction joint in lieu of the dowel bars.

SLAB REPLACEMENT CRITERIA

SLAB REPLACEMENT CRITERIA

In determining the need for slab replacements, consideration must be given to the extent and type of distress within a project. **The table at the bottom of this page lists good candidates for slab replacement.**

As noted under *Slab Replacement Consideration* (p.5), the following pavements may not be good candidates for slab replacements:

- Structurally deficient pavements:
 - Extensive cracking in relatively new pavements (<10 years old)
 - More than 10% 3rd stage cracking
 - Rapid development of new cracks.
- Pavements with moderate to severe material problem (e.g., ASR)
- Pavements with base or subgrade problems, as indicated by settlements.

For the conditions listed above, slab replacement is not an effective rehabilitation strategy. On such pavements, continued deterioration of the original pavement is likely to result in rapid redevelopment of cracking, spalling, and roughness. A better long-term repair solution for such pavements may be an unbonded concrete overlay, reconstruction, or crack

and seat and overlay with AC. In all cases, the cost of slab replacement should be compared against the cost of an overlay or reconstruction to ensure that slab replacement is cost effective for the project being considered.

In evaluating the appropriate rehabilitation strategy, consideration should also be given to the deterioration that may have taken place since the distress survey, especially if significant time has passed (e.g., more than 1 year).

Cracks in rigid pavements are not necessarily an immediate serviceability concern. Depending on traffic level and climate, cracked slabs can provide acceptable serviceability for an extended period of time. However, on roadways that carry high volumes of heavy truck traffic (e.g., $TI > 10$), cracks can rapidly deteriorate to a severity level that requires slab replacement. Traffic levels play an important role in the rate of deterioration, and they merit consideration in selecting distresses to be repaired with slab replacements. While the cracks are still low-severity, retrofitted dowel bars can be effective in preventing further deterioration.

All slabs with 2 or more corner breaks.

All slabs with third-stage cracking (see page 12).

Slabs with segments that are moving relative to each other.

Slabs with longitudinal or transverse cracks more than 13 mm wide. Depending on traffic level, lower-severity cracks may also need to be included to ensure that additional repairs will not be needed within the target rehabilitation design life.

Cracks with spalling and loss of concrete greater than 150 mm from the crack centerline and loss of aggregate interlock.

Slabs damaged by lack of support due to settlement, base failure, or excessive curling.

Guidelines for identifying slab replacement repair areas

TRANSVERSE JOINT ORIENTATION

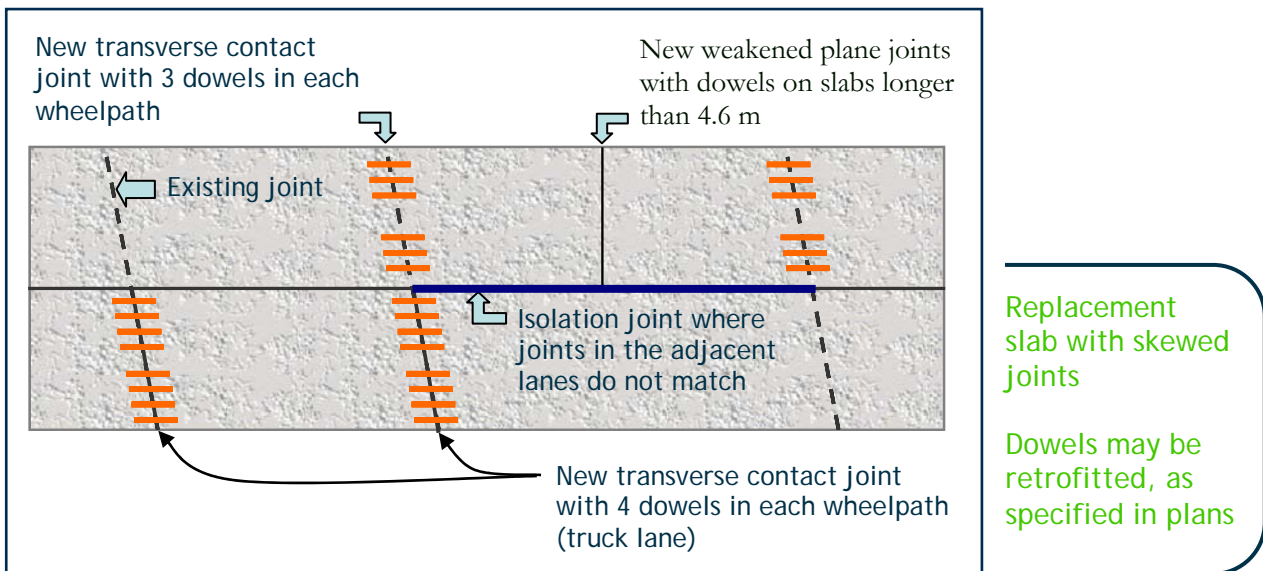
TRANSVERSE JOINT ORIENTATION

Transverse joints should typically match the spacing and skew of the existing pavement. Match existing skewed joints, especially on single slab replacements.

Where the joints in adjacent lanes do not match, the longitudinal joints require an expansion joint filler material to isolate the new concrete from the existing. This isolation joint will prevent the intermediate joint in the replacement slab from initiating cracking in the adjacent lane.

The illustration below is for instructional purposes only, where dowels are placed either by drill-and-bond method or retrofitted.

Special Case Illustration: use when placing dowels



LARGE AREA REMOVAL AND REPLACEMENT

LARGE AREA REMOVAL AND REPLACEMENT

A time-consuming and important step in the slab replacement process is preparing the transverse contact joints, which may include sawing the perimeter, drilling and grouting dowel holes, placing the dowels and expansion material, and sealing the joint. It is cheaper and faster to combine two closely located replacement areas into one large area, because this reduces the number of transverse contact joints to prepare. Replace a single slab between two slabs that are being replaced. A continuous pour typically

results in a long-term improvement of load transfer and smoother pavement.

If two replacement slabs are closer than the distances shown in the table, it is probably more cost-effective to combine them into one large slab. However, long panels have a tendency to crack at mid-slab; therefore, repairs longer than 4.6 m should be constructed with an intermediate weakened plane joint to prevent replacement slab cracking.

SLAB THICKNESS, mm	MINIMUM DISTANCE BETWEEN REPAIRS, m
180	4.0
205	3.4
230	3.0
255	2.8
280	2.4
305	2.4
380	1.8

Criteria for combining adjacent repairs for 3.6-m slab widths

Note: When two repairs are closer than the distances shown in the table, they should be combined into one large repair.



An example of two closely located repairs with existing slabs in between. A more cost-effective option may be to place one continuous repair with weakened plane joints.

DESIGN DETAILS AND ADJACENT-SLAB REPLACEMENTS

DESIGN DETAILS

The applicability of various design details depend on the desired performance life of the replacement slabs. Design features such as dowel bars, tie bars, and joint seal improve the performance life of replacement slabs. However, if the replacement slab only needs to last a short time (e.g., 1 yr) until the pavement can be reconstructed or overlaid, premium features are not needed. The recommended design details for different target performance lives are summarized in the table below, along with the criteria for replacing a slab.

ADJACENT SLAB REPLACEMENTS

On multiple-lane highways, deterioration of the slabs may occur in only one lane or across two or more lanes. If distress exists in only one lane, it is not necessary to repair the other lanes. When two or more longitudinally adjacent slabs contain distresses, generally one slab is repaired at a time so that traffic flow can be maintained. In such cases, an expansion

material, serving as an isolation joint, must be placed to separate the replacement slabs in the second lane from those in the first lane. The isolation joints prevent propagation of any movements from one slab to the next across the isolation joint, thus protecting the slabs from the effects of deleterious movements of the adjacent slab. The isolation joint will prevent damage to the newly placed replacement slab during the removal of the distressed concrete in the second lane. Once the deteriorated second lane slabs are removed, the expansion material between the two replacement slabs should be removed, provided the transverse joints in the adjacent lanes match.

FIELD DATA COLLECTION

Example field inspection and summary forms are shown in the following pages. Blank sheets of these forms are given in appendix A, starting at page a.7.

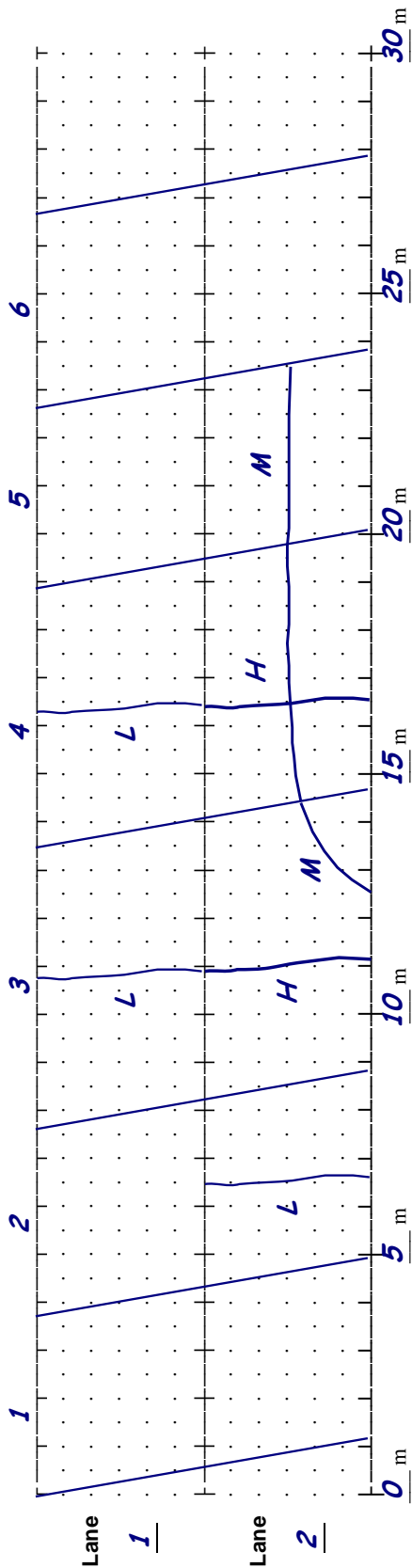
Pavement Condition	Emergency ≤ 1 year	Short term 1-5 years	Long term 5-10 years
Replace Slab?			
Slabs with 2 or more corner breaks	no	no	yes
Cracks making slabs < 2 m wide	no	yes	yes
Slabs with 3 rd stage cracks	no	yes	yes
Spalled and faulted cracks	yes	yes	yes
Loss of support and settlement	no	no	yes
Pumped fines on shoulder	no	no	yes
Design Feature	Emergency ≤ 1 year	Short term 1-5 years	Long term 5-10 years
Use the design feature?			
Dowel bars*	no	no	yes
Joint sealing	no	no	yes
Tie bars, if existing	no	no	yes
Large area replacement	no	no	yes
Diamond grinding	yes	yes	yes

Slab replacement selection criteria and recommended design features

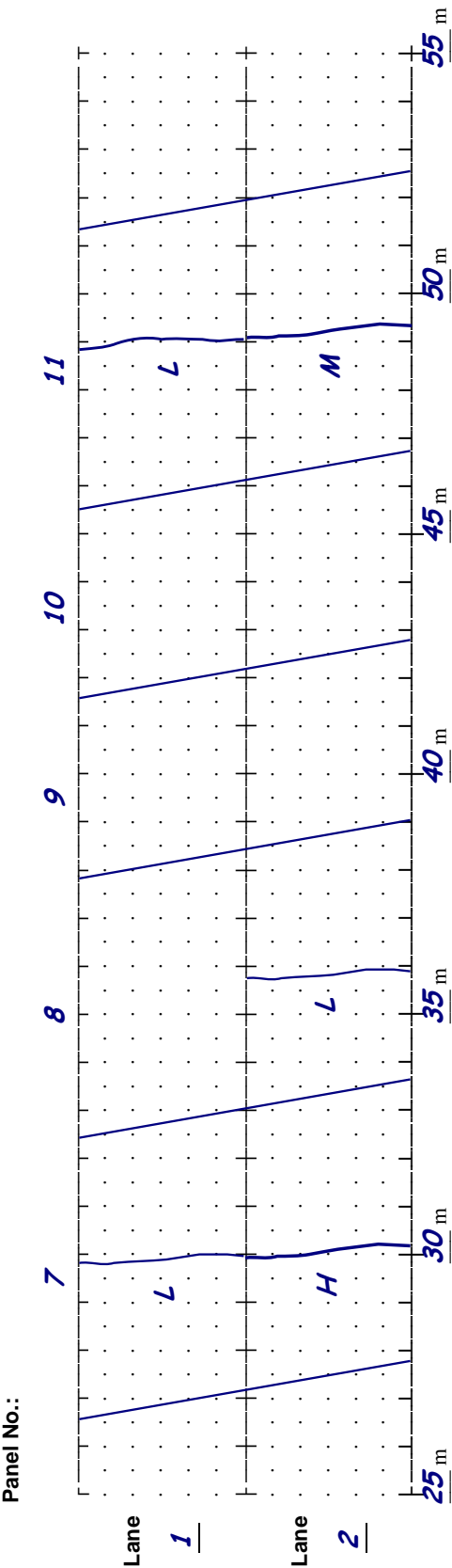
*If the construction window is less than 8 hours, do not install dowel bars by drill and bond method. Consider dowel bar retrofit

EXAMPLE DISTRESS MAP (SEE APPENDIX A)

CO-ROUTE-PM: SAC-50-2.1 Direction: EB Page: 1
Panel No.: _____ Date: 10/27/03



Comments: Slab no. 1 is 150 m from bridge # 18-141



Comments:

EXAMPLE FIELD DATA SUMMARY FORM (SEE APPENDIX A)

CO-RTE-PM: SAC-50-2.1

Date: 10/27/2003

Direction: EB

Lane	Panel No.	Cracking		Faulting mm	Pumping (y/n)	Other Distress	Photo no.	Comment
		Type	Severity					
1	3	TC	L	2	n		2	
1	4	TC	L	2	n			
1	7	TC	L	2	n			
1	11	TC	L	2	n			
2	2	TC	L	2	n			
2	3	TC	H	6	n		1	
		CB	M	4	n			
2	4	SS	H	5	y		3	
2	5	LC	M	6	n		4	
2	7	TC	H	6	n		5	
2	8	TC	L	2	n			
2	11	TC	M	3	n		6	

Cracking type:

TC = transverse; LC = longitudinal; CB = corner break

SS = Stage 3 (shattered slab with intersecting cracks)

Other distress type: ASR = Alkali-silica reactivity; R = Wheelpath rutting

Distress severity: transverse cracking

	Low (L)	Medium (M)	High (H)
Crack width (mm)	< 3 mm	≥ 3 mm; < 6 mm	≥ 6 mm
Faulting (mm)	< 2 mm	≥ 2 mm; < 6 mm	≥ 6 mm
Spall width (mm)	none	< 75 mm	≥ 75 mm

Distress severity: longitudinal cracking and corner breaks

	Low (L)	Medium (M)	High (H)
Crack width (mm)	< 3 mm	≥ 3 mm; < 13 mm	≥ 13 mm
Faulting (mm)	< 2 mm	≥ 2 mm; < 13 mm	≥ 13 mm
Spall width (mm)	none	< 75 mm	≥ 75 mm

24



Sample slab replacement log
(see appendix A)

SLAB REPLACEMENT					
Location (N/B or S/B, between which bridges, etc.)	Span				
	Panel No.	Lane No.	Ticket No.	Pour Time Begin	End
SB	1	1	1602	0230	0245
SB	2	2	1604	0240	0255
SB	3	1	1603	0235	0250
SB	4	2	1605	0245	0300
SB	5	2	1606	0250	0305

[illegible]

Sample slab replacement map (see appendix A)

Accurately defining slab replacement boundaries is essential to completing a project quickly. Engineering judgment is required in selecting slab replacement boundaries, particularly in areas exhibiting several types of distresses. Deterioration that is found outside of the planned replacement boundaries after work has begun requires additional time-consuming saw cuts and concrete removal.

slabs in the same lane. Partial slab replacement may be used on panels 4.6 m or longer. For panels shorter than 4.6 m, consider replacing the whole panel (rather than partial slab) based on labor costs. A replacement slab joint should be at least 2 m from the nearest crack or joint. This information can be noted in a slab replacement log and map, as shown in appendix A.

All slab replacement areas should be sawed as one linear cut and extend the full width of one slab.

NOTES

CHAPTER 3 CONCRETE MIX DESIGN



Batch plant

The contractor will select the replacement concrete material on the basis of the available lane closure time and the strength requirements (see Caltrans SSP). The state of the art in RSC pavement repair materials is such that virtually any lane closure requirement can be met. The opening concrete strength can be achieved by adjusting the cement type and admixture to accelerate the strength gain to as short as 4 hours. It should be noted that faster-setting mixes cost more and are usually more difficult to handle.

Although overnight repairs are routine today for slab replacement, it is preferable to provide for the longest cure time (several days) possible. When feasible, the longer curing time allows the use of conventional

concrete mixtures, which minimizes construction difficulties, and may increase repair life. **Therefore, a good rule of thumb in selecting the material for PCC slab replacement projects is to use the most conventional material that will meet the lane closure requirements.**

NOTE TO CONTRACTORS:

Good mix design and placement practices are extremely important to obtain durable concrete. Avoid using an excessively high water-to-cement ratio, placing concrete during excessively cold weather, and using too much retarding admixtures.

CONCRETE MIXES



Concrete mixing truck

Caltrans uses three types of RSC mixes for slab replacements:

- **Specialty or proprietary cement mixes** may be used on short construction windows and can meet opening strength requirements with 2 to 4 hours of cure time under typical placement conditions.
- **Mixes of Type III portland cement with non-chloride accelerators** may also be used for short construction windows and can meet opening strength requirements with 4 to 6 hours of cure time under typical placement conditions. A high-range water-reducing admixture may be used to disperse cement particles and reduce the extra water necessary for thorough mixing.
- **Mixes of Type II portland cement with non-chloride accelerators** may be used for longer construction windows. These types of mixes can achieve opening strength requirements with at least 24 hours of cure time under typical placement conditions.

Caltrans does not allow the use of calcium chloride (CaCl_2) accelerators to achieve high early strength. Calcium chloride is effective at ambient air temperatures over 32 °C, but it has the following detrimental effects on PCC pavements:

- CaCl_2 causes the concrete to shrink at twice the rate of the original mix, resulting in excessive shrinkage cracks throughout the slab. To prevent

random cracking, a shorter joint spacing is required.

- All ferrous material (tie bars and dowel bars) will corrode and expand, causing spalls. This is an ongoing process that will not stop until all the ferrous material is consumed.

The consideration of local climatic conditions is important in selecting a repair material. On hot days, solar radiation can raise the temperature at the slab surface significantly, adding to the temperature gradient and moisture loss. When the ambient air temperature is more than 32°C, it may be difficult to place some of the very fast-setting materials because they harden so quickly. Although a set retarder can be used with some of these materials to provide longer working times, a better solution may be to use a slower-setting mix.

While RSC should be placed with a minimum ambient air temperature of 13°C, it can be placed at a

WARNING

Caltrans does not allow the use of calcium chloride (CaCl_2) accelerators to achieve high early strength.

minimum air temperature of 5°C with special protection and cure.

TRANSPORTING RSC / POTENTIAL PROBLEMS



Volumetric truck

TRANSPORTING RSC

Concrete project planning is important for maintaining quality control. The ready-mix truck drivers are an important link in the quality control process. The planning should include a training or certification process to ensure that the drivers have the following knowledge and skills:

- How to retard a mix that is setting or "going off" in the mixing drum.
- Emphasis on the importance of timely washouts.
- No stops should occur between the batch plant and the job site.
- No additional mixing water should be added during hauling or after arrival at the delivery point unless authorized by the engineer.
- Trucks must leave the batch plant with full water tanks.
- Haul tickets should include the date and time the truck left the plant, the time it arrived on the job site, and the time it left the job site. Water added at the job site, if any, should be noted.
- If admixtures are added at the job site, quantities should be noted on the haul ticket.
- The maximum recommended number of revolutions is 250.

Ready-mix plants and volumetric trucks should have a current CT 109, *Method for Testing of Weighing and Measuring Devices*.

POTENTIAL PROBLEMS AND PRECAUTIONS

Due to the rapid hardening and strength gain of RSC mixes, there is often a build-up of concrete ingredients inside the transit mixing truck. If allowed to cover the fins of the truck, this build-up will result in a segregated mix and reduced carrying capacity.

The driver should wash the mixing drum with a high-pressure water hose after each delivery, and the truck should be taken off-line for chipping when the fins are covered with hardened concrete, causing segregation. The uniformity requirements in Annex A1 of ASTM C94 may be used as a guide to evaluate the need for taking a truck off line. It is also common practice to take the truck out of service for chipping when the weight of the truck indicates there is excessive build-up in the mixing drum.

The contractor must pay attention to all details when using RSC, including cement storage. Contamination of calcium sulfo-aluminate-based cement with conventional portland cement can result in a permanently plastic condition (does not harden). Admixtures, such as a set retarder or accelerator, must be dosed carefully according to the approved mix design. Misdosing any accelerated mix can result in flash- or false-setting, either in the mixing truck or on grade, before the mixture can be placed and finished.

TRIAL SLAB CONSTRUCTION



Flexural beams
at trial slab

TRIAL SLAB CONSTRUCTION

Prior to beginning work on the actual project, the contractor must successfully complete one or more trial slabs for each concrete mix design to be used in the project. The trial slabs should be constructed off site at approximately the same time (typically at night) and temperature conditions as those anticipated during slab replacement construction. Trial slabs should be constructed, finished, cured, and tested with the materials, tools, equipment, personnel, and methods to be used in completing the replacement concrete pavement repairs.

The trial slab should demonstrate that the contractor is capable of producing slab replacements in conformance with Caltrans' specifications. The same cement source used for the trial slab must be used throughout the entire project.

CHAPTER 4 CONCRETE SLAB REMOVAL



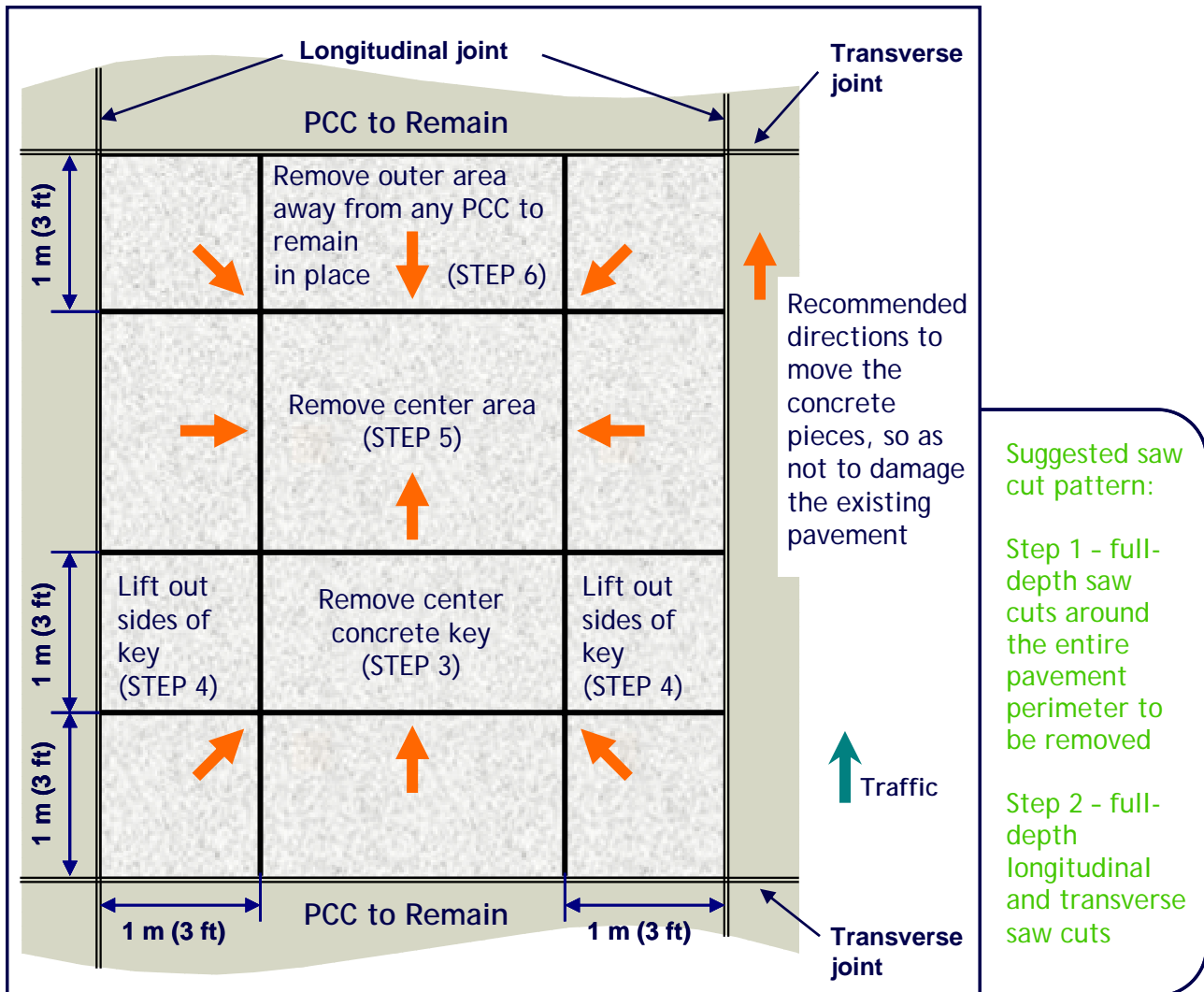
Full-depth saw cut
& slab removal

SAW CUTS

Full-depth saw cuts must be made around the entire perimeter of the distressed concrete area that will be removed. The area removed must be at least 2 m long. In addition, any remaining concrete adjacent to the removed concrete slab must also be at least 2 m long. Therefore, for safety and pavement performance, no new or existing slab, can be less than 2 m long. Any slab that does not meet this requirement should be removed.

The saw cuts may be made up to two days prior to slab removal to ensure that the sawing operation will not hold up the slab removal and replacement process. Full-depth saw cuts separate the segment of deteriorated concrete and also allow room for its removal with no damage to the surrounding pavement.

SAW CUTS AND CONCRETE REMOVAL



The following guidelines should be followed during saw cutting:

- Saw the concrete in rectangular sections to simplify concrete removal.
- Do not make notches or diagonal cuts in the pavement.
- Each area of concrete to be replaced will receive a saw cut through the existing slab around its entire perimeter. Additional sawing of individual panels will be required for slab removal.
- Saw cuts through the existing slab are required to separate the removal area from the surrounding concrete.
- Water residue from concrete cutting should be removed immediately by vacuuming.
- Saw cuts made prior to the actual removal work shift should not include any cuts made closer than 1 m to another cut, joint, or crack, so as to avoid creating any small pieces that could be dislodged by traffic.

SLAB REMOVAL TECHNIQUES



Step 3-Remove concrete key with lift pin

Step 4-Use lift pin to remove concrete key across the pavement width



Step 5-Remove center portion of the repair area with a bucket, working away from PCC to remain in place

SLAB REMOVAL TECHNIQUES

Caltrans does not allow removal techniques that may damage the remaining in-place pavements and base. Therefore, Caltrans typically requires that non-impact methods be used for reducing the concrete slab size for removal. Caltrans may allow hammer removal (impact method) when the treated base needs to be removed.

SLAB REMOVAL

The deteriorated concrete must be sawed into manageable pieces, so that the pieces can be lifted out of place without breaking. Lifting out the old concrete in pieces minimizes damage to the base and subbase. It is usually faster and requires less labor than breaking the concrete before removal.

The most common lift-out method uses a steel chain connected to the lift pins. Other time-saving lift

equipment includes forklift devices and torque claw attachments for front-end loaders.

Equipment used to remove concrete pavement within the sawed outline should not damage the adjacent or remaining concrete. Pavement and base removal should be performed without damaging the pavement or base that remains in place. Damage to pavement or base that remains in place should be repaired or removed and replaced by the contractor to a condition acceptable to the engineer. No compensation will be allowed to the contractor for the repair, or removal and replacement, of the damaged pavement or base material.

Removed material should be disposed of outside the highway right-of-way in conformance with Caltrans Specification 7.1.13, "Disposal of Material Outside the Highway Right of Way."

SLAB REMOVAL TECHNIQUES (CONTINUED) / POTENTIAL PROBLEMS



Impact method may only be used for full-depth pavement and treated base removal



Pavement section thicker than shown on the plans

SLAB AND TREATED BASE REMOVAL

Caltrans does not approve any impact slab removal techniques, with the exception of pavement sections where both the PCC pavement and treated base are to be removed. For slab and treated base removal, the contractor may use a non-impact method of pavement and treated base removal, if desired.

POTENTIAL PROBLEMS

Even when the proper procedures are followed, problems can occur during the slab removal. Some of the more common problems that have been encountered during slab removal are:

- The slabs are thicker than indicated on the plans.
- Slabs were previously replaced with a monolithic slab and treated base repair and are not representative of the typical pavement cross-section.

Remember that when existing slabs are thicker than shown on the plans, additional concrete may need to be ordered, or work for the night should be limited to match the quantity of concrete ordered.

Other typical problems may include:

- Pre-sawing did not extend through the entire slab depth.
- Slabs may shatter when lifted.
- Base material may bond with the slab.

When problems occur, additional saw cuts and removal of any in-place pavement damaged during the initial slab removal may be required using appropriate slab replacement techniques. Engineering judgment must be used to remedy these situations as they occur in the field.

CHAPTER 5 BASE PREPARATION



Completed subgrade preparation

Subgrade compaction



INSPECTION

SLAB REPLACEMENT

Following slab removal, inspect the surface of the underlying CTB or LCB base in a timely manner. The poor base conditions that may require removal and replacement include the following:

- Pockets of loose or missing material
- Damage due to slab removal activities
- Broken-up and loose base
- Excessively wet areas of base material

Occasionally, portions of the treated base may be attached to the PCC being removed.

- Minor base removal can be repaired quickly using RSC. All RSC used must have enough strength to resist deformation from construction personnel and equipment prior to the placement of the pavement layer. Deformed RSC base repair patches will result in premature failure of the replaced slabs.
- If slab removal has caused excessive damage, such as significant removal of the base surface or excessive fracturing of the base material, the base must be removed and replaced with RSC.

SLAB AND TREATED BASE REPLACEMENT

Following slab and treated base removal, inspect the surface of the underlying subgrade layer in a timely manner.

Identify subgrade conditions that require repairs:

- Pockets of loose or missing material
- Excessively wet areas of subgrade material
- Damaged subgrade due to base removal activities

Small areas of missing or disturbed subgrade can be repaired quickly by recompacting. If slab removal has caused excessive damage, such as significant removal of the subgrade, fill the damaged areas with concrete as part of the base material pour.

REPAIR SELECTION



Slab replacement: be sure to remove any standing water prior to placing material



Slab and treated base replacement

REPAIR

SLAB REPLACEMENT

Good Condition. When the treated base is in good condition, which will be the case in most instances, only minimal repairs are required. Repairs may consist of minor surface preparation of the base material, such as using RSC to patch portions of base material that were damaged during slab removal.

Poor Condition. Treated bases that are in poor condition should be removed and replaced. Replace the base materials which are removed from the required repair area with RSC. A bond breaker is required between the replacement base and the surface layer. Any extensive base repairs will reduce the number of slab replacements that can be performed in a single shift.

SLAB AND TREATED BASE REPLACEMENT

The material remaining in place, after removing the pavement slab and base, should be graded to a uniform plane, moisture conditioned, and compacted by methods that will produce a firm and stable base course.

If the subgrade is muddy, wet, or soft, consider using a geo-grid material as a construction platform. The finished surface of the remaining material should match the grade of the existing subbase. Areas that are low as a result of over- excavation during base removal should be filled with base replacement material at the contractor's cost.

The treated base shall be placed as a separate pour and allowed to harden. In this situation, the treated base layer should be constructed at the same elevations as the surrounding treated base. Once properly cured, a bond breaker can be applied to the treated base surface and a new pavement slab poured.

See page 3 for a discussion on placing RSC for slab and treated base repairs under extremely narrow construction windows.

BOND BREAKER



Bond breaker placement
in slab and treated base
replacement

BOND BREAKER

The bond breaker allows the slab and base to move independently of one another. Due to the tight construction windows typically encountered during slab replacements, it is recommended that a suitable plastic sheeting bond breaker be applied over the prepared base. A curing paper may also be used as a bond breaker. Occasionally, if time permits, other bond breaker materials may be used per contract specifications.

The base replacement material and RSC pavement shall not be placed in a monolithic pour.

All concrete material applied to the underlying pavement layers must have an initial set prior to placement of the bond breaker material.

Existing concrete pavement and the underlying base material should be removed and replaced with new base material and RSC pavement within the same work period. In the event that the existing pavement or base materials are removed and the contractor is unable to construct, finish, and cure the repair prior to the specified traffic opening time, slab removal areas shall be filled with standby material according to the contractor's contingency plans and compacted in conformance with the contract specifications.

NOTES

CHAPTER 6 PAVEMENT JOINT PREPARATION



Gang drill for dowel bar installation

All existing pavement joints that border the slab replacement area must be prepared immediately prior to placement of the fresh concrete. This preparation consists of placement of dowel bars, tie bars, and expansion materials.

DOWEL BAR INSTALLATION

For most repairs of jointed pavements, doweled transverse joints are essential for load transfer. The recommended number of dowel bars and bar spacing are discussed on page 17 under *Load Transfer Design*. All dowels must be placed parallel to the longitudinal joints.

Caltrans typically recommends the following dowel diameters:

- 38-mm diameter dowel bars provide effective load transfer for slab replacement in highway pavements
- For pavements less than 180 mm thick, dowel bars are not recommended

Dowel bars should be placed at two locations within each slab replacement boundary: at the transverse

interface between the new and old PCC pavement (transverse contact joints) and at the sawcut joints within the new slabs (transverse weakened plane joints), aligned with the longitudinal edge of the slab.

TRANSVERSE CONTACT JOINTS

Automatic dowel drilling equipment produces straight, consistent holes faster than single, hand-held drills. Modern dowel drilling equipment is mounted on a boom or on a frame with wheels that are maneuverable on a job site. If proper slab removal dimensions are selected, adequate space will allow for automatic dowel drilling equipment operation. To improve consistency, single, frame-mounted, or hand-held drills should not be used.

Either standard pneumatic or hydraulic percussion drills are acceptable for drilling dowel holes. Both drill a typical dowel hole in about 30 seconds. Avoid electric-pneumatic rotary drills where speed and production are essential, because they take three to four times longer to drill each hole.

TRANSVERSE CONTACT JOINTS



Contact joint with
dowels and
expansion caps



Note: End caps are
not needed if a
portland cement
mix is used, which
shrinks

Weakened plane
joint with dowels
(without expansion
caps)

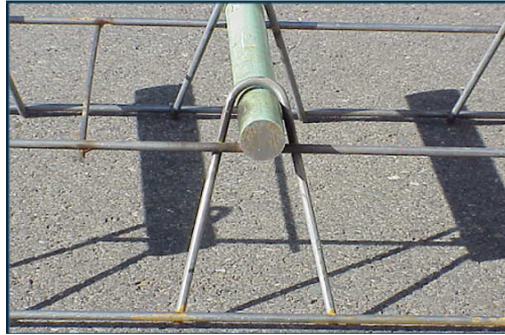
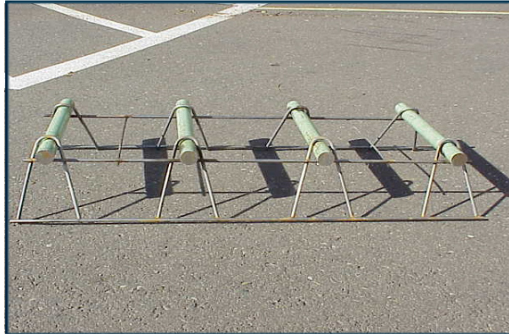
After drilling, clean out the dowel holes by inserting an air nozzle into the hole to force out all dust and debris. Dust and dirt prevent the epoxy or non-shrink grout from bonding to the concrete around the perimeter of the hole. Oil also prevents good bonding. Therefore, always check the air for oil and moisture contamination from the compressor by blowing some air into a piece of dry cloth.

Caps must be placed on one end of each transverse contact joint dowel, if a non-shrink cement mix will be used. A good rule of thumb is that all cements that are not portland cement may be considered non-shrink. Dowels that are drilled and bonded with epoxy do not need caps on the side placed in the drilled hole.

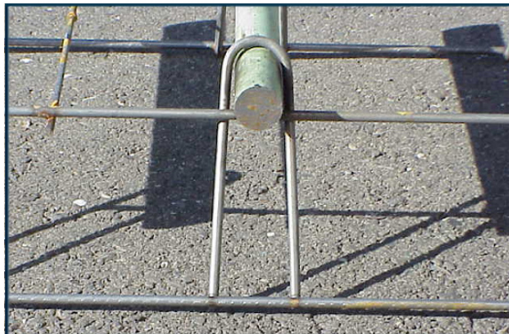
Place the anchoring material using a long nozzle that feeds the material to the back of the hole. This ensures that the anchoring material will flow forward along the entire dowel embedment length during insertion and decreases the likelihood of leaving voids between the dowel and the concrete. Prefabricated epoxy cartridges are available that supply enough material for one or two holes, but a faster and less expensive system for large projects is to use a pressurized injection system from bulk epoxy containers.

As dowel bars are placed, they should be rotated gently to coat the dowel with epoxy and provide uniform bonding.

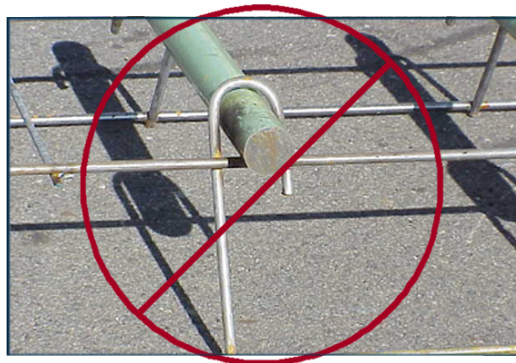
TRANSVERSE WEAKENED PLANE JOINTS



A-Type
dowel bar
basket



U-Type
dowel bar
basket



J-Type dowel bar basket
(not allowed)

TRANSVERSE WEAKENED PLANE JOINTS

Dowels should be placed at all weakened joints within a slab repair using type A or U baskets. Type J baskets do not meet the Caltrans specifications and are not allowed.

See page 19 for guidelines on transverse joint orientation.

Each basket must be anchored securely with approved concrete fasteners (for a 3.65-m-wide slab)

that are evenly spaced at 0.3 m to hold all dowels firmly at the specified depth and alignment. Once the baskets are anchored, cut the manufacturer's tie wires.

Expansion caps are not needed for weakened plane dowel basket assemblies because dowel bars are greased and cured RSC shrinks away from the saw cut.

TRANSVERSE WEAKENED PLANE JOINT (CONTINUED)



Cut tie wires

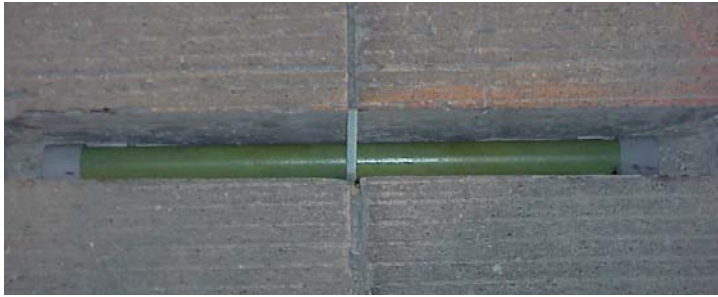
Once the dowels are placed, and prior to concrete placement, watch for any signs of misalignment during the concrete placement. Misalignment of the dowels will lead to increased stresses within the new concrete pavement and result in premature cracking and failure of the repaired pavement section.

Where the existing transverse weakened plane joint spacing in an adjacent lane exceeds 4.6 m, an additional transverse weakened plane joint must be constructed midway between the existing joints (see p. 19 for illustration).

TIE BAR INSTALLATION

Caltrans currently uses tie bars on all longitudinal joints on new construction. Tie bars are placed perpendicular to the longitudinal contact joint at a pavement depth (D) equal to $D/2$. Tie bars between existing slabs and "newly placed" concrete should only be placed if the existing pavement has tie bars. Tie bars help mainly to keep lanes from separating. See the table on page 21 for guidelines on when to use tie bars on slab replacements.

DOWEL BAR RETROFIT



Retrofit dowel bar
on PCC surface



Retrofit dowel bars
placed in PCC
pavement slots

DOWEL BAR RETROFIT

For contact joints, dowel bar retrofit may be used if dowels were not installed during the slab repair. Drilling, cleaning, and epoxying the dowel bars into the existing concrete may require more time than is allowed on the construction site. Therefore, retrofit dowel bars may be selected due to a narrow construction window. Dowel bar retrofit should be installed according to Caltrans' standard specifications and plans. Dowel bar retrofits may be installed after the slab replacement has been opened to traffic, during one of the following construction shifts.

PAVEMENT JOINTS



Expansion material

PAVEMENT JOINTS

After installation of all required dowel bars and immediately prior to concrete placement, the transverse and longitudinal pavement joints must be prepared properly.

TRANSVERSE CONTACT JOINTS

A 6-mm-thick, commercial-quality polyethylene flexible foam expansion material must be placed securely across each transverse contact joint. This material must extend along the slab face, with the top of the expansion material flush with the top of the pavement. In addition, the expansion material must be cut to fit with holes for drill-and-bond dowels.

The expansion material should be secured to the face of the existing pavement joint, and concrete should not be allowed to get between the expansion material and existing rigid pavement. If fresh concrete does get between the expansion material and the existing pavement, spalling will likely occur in the near future.

LONGITUDINAL CONTACT JOINTS

Expansion materials are not required along the longitudinal contact joint for isolated pavement slab repairs of only one slab, unless the joints of adjacent slabs do not match. Expansion materials may also be used along longitudinal contact joints if the adjacent pavement slabs are scheduled for replacement. Use of the expansion materials prevents bonding at the longitudinal joint and will reduce slab removal and replacement times.

If expansion material is used along the longitudinal joints, it must be placed securely across the entire length of the joint and extend along the height of the slab, with the top of the expansion material flush with the top of pavement joint.

CHAPTER 7 CONCRETE PLACEMENT & INSPECTION



Overview of slab replacement contact joint, and weakened-plane joint with dowel bar basket & bond breaker materials prior to the concrete pour

The following inspections procedures apply before, during, and after concrete placement.

PRE-POUR INSPECTION

Immediately prior to concrete placement, the bond breaker, dowel and tie bars (when specified), and expansion material must be inspected to ensure proper placement.

BOND BREAKER INSPECTION

Typically, plastic sheeting will be placed as the bond breaker over the existing base material. Ensure that it is placed flat, with a 150-mm overlap where necessary and with as few wrinkles as possible, with minimal overlapping of the same sheet.

Occasionally, a curing paper or coating may be applied, such as asphalt emulsion or pigmented curing compound. Verify that it has not been damaged since the installation and reapply if needed.

DOWEL BAR INSPECTION

Prior to concrete placement, check that all dowels are installed properly (when specified). All dowel bars must be placed parallel to the direction of slabs (longitudinal joint).

- For dowels set in the contact joints, each dowel should have an expansion cap located on the exposed end of the dowel bar, if a non-shrink mix (non PCC mix) will be placed. The expansion cap is not required for PCC mixes.
- For weakened plane dowel assemblies, verify that the dowels and dowel basket assemblies are fastened properly and aligned.

EXPANSION MATERIAL INSPECTION



Transverse expansion joint material



Longitudinal expansion joint material



Failed attempt to fasten expansion material securely

EXPANSION MATERIAL INSPECTION

The expansion material must be cut to fit the holes for drill-and-bond dowel bars and tie bars. Additional expansion material may also be placed along the longitudinal joint if the adjacent slab will be replaced later.

CONCRETE PLACEMENT



Concrete placement



Poor construction practice. Concrete is beginning to set before final placement. Also, the concrete chute is being cleaned over the repair area.

DURING-POUR INSPECTION

CONCRETE PLACEMENT

As fresh concrete arrives on the job, the inspector should monitor the concrete temperature and watch for cement balls in the truck. Lumps of unmixed cement will affect the quality of the concrete by reducing the cement content of the remaining batch. If this occurs, reject the load. Usually, cement balling can usually be corrected by changing the batching sequence, such that cement does not come in contact with mix water directly in the drum.

The chute operator should distribute the concrete evenly to avoid the need for excessive shoveling. Attaining good concrete consolidation around dowel bars and along the patch perimeter is important to

achieve long-term performance. Vertical penetrations of a standard spud vibrator will mobilize the fresh concrete adequately. Do not drag the vibrator through the mix because this may cause segregation.

WARNING:

RSC has a high slump, typically 200 mm or more. When poured on a slope, RSC can flow down the slope until it sets. High-sump RSC should be placed starting at the lowest point.

SPREADING, COMPACTING, AND SHAPING



Uniform concrete placement using the concrete truck chute



Concrete vibration without dragging the vibrator and hand finishing



SUMMARY OF SPREADING, COMPACTING, AND SHAPING

- Metal or wood side forms may be used. When wood side forms are used they should not be less than 40 mm thick.
- Side forms should remain in place until the pavement edge no longer requires the protection of forms. Side forms should be cleaned thoroughly and oiled prior to each use.
- RSC should be consolidated using high-frequency internal vibrators. Through proper application of vibration uniform consolidation should be achieved adjacent to the forms and across the full paving width.
- RSC should be placed, as nearly as possible, in its final position, and vibrators are not permitted for shifting of the mass of RSC.
- RSC should be spread and shaped by suitable powered finishing machines, supplemented by hand finishing as necessary. Methods of spreading, shaping, or consolidating that result in segregation,

voids, or rock pockets should be discontinued. The contractor should use methods that will produce a dense homogeneous pavement conforming to the required cross-section.

- After the RSC has been mixed and placed, no additional water should be added to the plastic concrete. There are several approved retarding agents, which may be used to facilitate the finishing of the slab surface.

NOTE:

No cold joints are allowed. Make sure that there is enough RSC to pour the entire slab. If not enough RSC is on site to complete the slab, remove the concrete back to the previous transverse joint and place a construction joint.

CONCRETE SAMPLING AND TESTING



Sample preparation area

Preparation of concrete beams



Concrete sampling



Beams protected and placed on last constructed slab to cure

CONCRETE MATERIAL SAMPLING AND TESTING

The contractor may be required to hire a testing laboratory to conduct the required Caltrans tests. Caltrans staff will supervise the contractor sampling and testing.

During concrete placement, adequate amounts of concrete material should be obtained to conduct the required Caltrans tests (the sampling and testing procedures are summarized in appendix B). The sample material may be placed in a wheelbarrow. To ensure accurate testing results, representative samples should be obtained from the middle portion of the batch as soon as possible. Under no circumstances should the elapsed time between the first and final sampling of wet concrete exceed 15 minutes.

The material samples may be obtained from a stationary mixer, paving mixer, revolving drum truck

mixer or agitator, open-top truck mixer, agitator, non-agitating equipment, or other types of open-top containers.

After a composite sample is obtained, the material should be placed in beam molds and allowed to set. The beams should be protected and placed on top of the last constructed curing slab to maintain the consistency of curing between the beam molds and the fresh concrete.

A Caltrans laboratory may conduct additional strength testing. These tests are used to determine payment to the contractor and acceptance of the pavement.

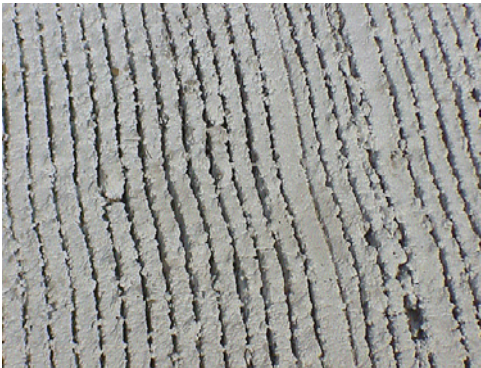
SURFACE TEXTURING



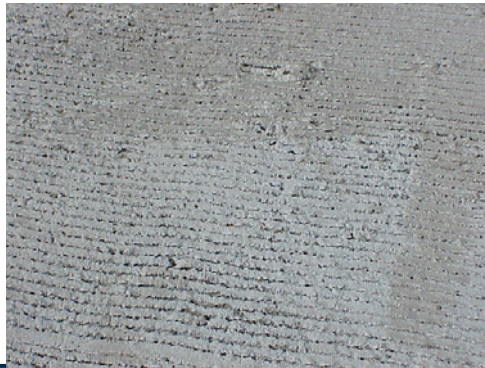
Tining should be applied parallel to the pavement centerline



Avoid overlapping the tining comb or digging too deep



Tining applied too early before the initial set can cause raveling of the concrete surface



Unsatisfactory workmanship resulting in rough surface

Improper tining techniques

AFTER CONCRETE PLACEMENT

Immediately after placement, surface texturing, saw cutting, and curing are critical to the final condition of the concrete surface.

SURFACE TEXTURING

Surface texturing by tining can begin immediately after the placement of the fresh concrete and must match the texture of the existing pavement surface. The texturing should be applied in one continuous pattern. The texture pattern should not overlap and should appear uniform over the entire pavement surface. See Caltrans Standard Specification 40-1.10, Final Finishing.

CURING



Power-operated cure



Hand cure should be used only when the work area is inaccessible to the power operated equipment

CURING

Curing of the fresh concrete is critical to the long-term performance of the replaced slab and must occur in a timely manner. Shortly after placement, the slab must be sprayed with curing compound or cured as recommended by the manufacturer of the hydraulic cement used in the RSC. Insulating layers, such as plastic sheeting, can be placed on the pavement surface to promote the hydration of the concrete resulting in faster strength development.

For high-early-strength mixes, the first few hours after placing the concrete are the most critical. Proper curing is essential to maintain a satisfactory moisture and temperature condition in the concrete after placement. As soon as possible, apply the curing compound and cover with plastic sheeting for proper curing.

SAWING TRANSVERSE JOINTS AND FINAL FINISH



Weakened plane joint being sawed



Late or shallow sawing can contribute to volunteer cracking



Planned PCC joint



Unplanned PCC joint caused by volunteer crack

SAWED WEAKENED PLANE JOINTS

Transverse joints in the replacement pavement should match the spacing and skew of the existing pavement. For slabs longer than 4.6 m, an intermediate sawed weakened plane joints should be provided at midslab. Sawed joints should be cut to the depth specified. If the sawcut depth is not specified, the joint should be sawed $t/3$, where t is the slab depth. The sawcuts should be made to the minimum width, not to exceed 6 mm for joints that will not be sealed.

Sawing of weakened plane joints should be completed as soon as the concrete will support the saw. Refer to Caltrans Specification 40-1.08B(1), "Sawing Method." Sawing for joints to be sealed should conform to Caltrans Standard Plan A35C.

PROTECTING NEWLY PLACED SLABS

Newly placed slabs must be protected according to Caltrans Specifications 7-1.16, "Contractor's Responsibility for the Work and Materials," and 90-8, "Protecting Concrete." To protect slabs from vehicles driving through them, the contractor should:

- Place "Wet Concrete" signs on barricades and place cones around the entire perimeter of the replaced slabs.

- Make sure that the cones and barricades are not placed on the new concrete slabs, as they will leave impressions and damage the surface finish.

FINAL FINISHING

Tests to determine the coefficient of friction of the final textured surface will be made only if the engineer determines, by visual inspection, that the final texturing may not have produced the specified coefficient of friction.

Any tests to determine the coefficient of friction will be made after the pavement is opened to traffic, but not later than 5 days after concrete placement. Pavement areas having a coefficient of friction as determined in conformance with California Test 342 of less than 0.30 should be grooved in conformance with the Caltrans Standard Specifications.



Caltrans skid testing machine

CHAPTER 8 OPENING TO TRAFFIC



Opening to
traffic

Before the replaced slab can be opened to traffic, the engineer must ensure that the repair area has gained specified strength and that the site has been cleaned up.

FLEXURAL STRENGTH TESTING

Variations in air temperature, humidity, wind speed, and mix temperature can have a great effect on strength development of RSC. The goal of curing the beams for flexural testing is to have the strength of the beams match the strength of the pavement. Following Caltrans test procedures will help ensure this.

It is important to remember that the Caltrans field laboratory will contact the designated inspector with

the test results from the concrete flexural strength specimens. These flexural strength test results are not used as the criteria for opening to traffic. The Caltrans field laboratory flexural strength test results are used to determine pay factors for the contractor, as the contractor may choose to open the lanes to traffic at less than specified strength to avoid penalties associated with delays.

OPENING TO TRAFFIC (CONTINUED)



Slab replacement

CRITERIA FOR OPENING TO TRAFFIC

The opening to traffic strength is based on a minimum flexural strength of 2.8 MPa, as determined in accordance with CTM 523 (see Appendix B, page b.6).

If the slabs have not reached their flexural strength prior to opening the lanes to traffic, that portion of the job remaining should be considered temporary and must be replaced. The contractor will be required to return the next shift and replace the temporary slabs.

PAVEMENT DELINEATION REPAIR

Whenever pavement delineation is removed or damaged due to work involved within the project limits, the contractor should replace or repair the delineation to its original condition at the contractor's expense. Pavement delineation repairs should be made in conformance with the provisions in Section 84, "Traffic Stripes and Pavement Marking," and Section 85, "Pavement Markers," of the Caltrans Standard Specifications.

CLEAN-UP

The contractor must supply a sweeper at the end of concrete placement for each work period. Direct the sweeper to clean specific areas as necessary. If needed, have the sweeper clean around the area of the washout pit. Replace any pavement markers that were removed during the work shift. Touch up any traffic striping that was obscured or damaged during the shift.

CHAPTER 9 GRINDING & JOINT SEALING



Diamond-ground concrete

Diamond grinding should always follow slab replacement to reduce roughness and improve ride quality. Joint sealant, where specified, should be installed after completion of the slab replacements and after any required diamond grinding activities. Only the sawed joints shall be sealed.

NOTE TO DESIGNERS:

Be sure to include item to diamond grind!

DIAMOND GRINDING

Diamond grinding corrects irregularities by removing a thin layer of hardened concrete, using closely spaced diamond saw blades. The grinding operation normally removes between 4 and 6 mm per pass and results in a smooth, quiet, longitudinally grooved surface texture.

Ride quality measurements shall be used to determine when grinding is necessary. After slabs are replaced, measure the surface variance and joint differential. Variances greater than 2.5 mm affect ride quality. For slab replacements with a variance greater than 2.5 mm, diamond grinding is required.

Diamond grinding can extend serviceability, improve ride and skid resistance, and reduce pavement noise. Diamond grinding has been used as a PCC pavement rehabilitation strategy for the following purposes:

- Transverse joint and crack fault removal (primary reason)
- Removal of wheel path rutting caused by studded tires
- Removal of permanent slab warping or curling at joints (in very dry climates where significant warping has occurred)
- Texturing of polished concrete surface exhibiting inadequate friction
- Improve transverse slope
- Improve ride quality by removing faulting, surface roughness, and unevenness caused by slab replacement
- Reduce noise and provide a safe, long wearing surface texture

DIAMOND GRINDING (CONTINUED)



Acceptable diamond grinding



Note the vertical fins and irregular grooves

Unsatisfactory diamond grinding

Do not attempt to remove depressions that are deeper than 9 mm by diamond grinding. Profile measurements along the project in each lane are an excellent indicator of depressions and bumps.

The most effective approach for grinding is to grind the entire lane width, which requires several passes. The reason for grinding the entire lane width is to avoid creating multiple longitudinal steps in the pavement.

Using adjacent slabs as guides and forms while performing slab replacements may result in steps or bumps where none existed before and should not be allowed.

Once diamond grinding is completed, roughness profile measurements are an excellent way to verify that the desired pavement profile has been achieved. Remember to replace any removed lane markers prior to re-opening to traffic.

JOINT SEALS

JOINT SEALS

The entrance of fines or incompressibles and surface water into the joints may contribute to faulting, joint spalling, excessive pressure against bridge abutments, and pavement blowups. This is especially critical on high-elevation routes where sanding is used during icing conditions, and also in sand-blown areas where fine sand is deposited on the road.

With recent developments in joint design and sealant materials, it is evident that joint sealing can be quite cost-effective, provided that careful attention is given to selection of materials and construction of the sealed joints.

Because of the factors mentioned above and to minimize the need for costly and disruptive repairs on heavily traveled urban freeways, sealing of all joints is required on new concrete pavements. However, when lanes are added for widening, the joints should not be sealed unless the transverse and longitudinal joints (and cracks) in adjacent lanes are also sealed. Where specified, sealant should be placed within 7 days of opening to traffic, so that incompressibles do not fill the joint.

JOINT CLEANING

The most critical phase of joint sealant installation is the cleaning of the joint. The concrete must be dry and curing complete. Following the sawing operation, the joint must be sandblasted. This operation should provide a visibly clean new surface along both sidewalls, which should be visible from a surface inspection of the joint.

Air blasting is an effective way to remove the fine material from the joint sidewall. The nozzles of some sand blasting equipment have been modified with deflectors to direct the sand against the sidewalls to provide a clean surface. Air blasting is not designed to remove old sealants and should never be performed in lieu of sealant removal.

Care is required to remove the laitance or cement dust produced by the sawing operation. This dust is not removed with water cleaning and prevents the sealant from bonding with the sidewall. It does not hurt the joint to flush it with water to assist in the removal of incompressibles, but washing is not sufficient to ensure good bonding.

The joint must be completely dry before proceeding with the sealant installation.

SEALANT INSTALLATION

When joints are to be sealed, the joint dimensions (shape factor) and preparation are critical to good performance and must be constructed per Caltrans Standard Plans (RSP A35C).

NOTES

APPENDIX A SLAB REPLACEMENT CHECKLIST



Slab and treated base replacement

PRE-CONSTRUCTION

- ❑ Review Plans, Specifications and Special Provisions for special information, completeness, and accuracy
- ❑ Prepare yourself and your staff for night work, if necessary
- ❑ Kick-off meeting with designer (Pre-Job Meeting)
 - ⇒ Clarify design intent
 - ⇒ Clarify location of slabs to be replaced
 - ⇒ Clarify plans and specifications
 - ⇒ Lessons learned from past experiences
- ❑ Material testing
 - ⇒ Review Standard Specifications
 - ⇒ Review Special Provisions
 - ⇒ Prepare to sample and test beams
 - ⇒ Ensure that testing staff is certified to perform the required testing
 - ⇒ Submit samples of cement and admixtures to METS for testing
 - ⇒ Submit sample aggregate source for testing by District Lab
 - ⇒ Review contractor's quality control plan, if specified
- ❑ Plant inspection
 - ⇒ Review Special Provisions, weightmaster certificates, material stockpiles, control room operations
 - ⇒ Batch or volumetric mixing requirements, general requirements of the cement, proportioning, and weight certificates
 - ⇒ Check for proper plant certification (CT 109)
 - ⇒ Mix design
 - ⇒ Prepare to provide plant inspection services
- ❑ Notify field laboratory for them to provide plant inspection service
- ❑ Create list of Submittals (CEM-3101)
- ❑ Project awarded—request for mix design and samples that need to be sent to Translab
- ❑ Schedule Just In-Time Training (JITT), prepare CCO if necessary
- ❑ Review Contingency Plans
 - ⇒ What to do when things go wrong
 - ⇒ Plant or equipment breakdown
 - ⇒ Modulus of rupture does not meet requirements for opening to traffic

- ❑ Set up trial slab for each mix design
- ❑ Before the start of each work week:
 - ⇒ Plant inspection request: sample cement for shipping to Translab, test aggregate for gradation and cleanness value (CV)
 - ⇒ Strength testing request: modulus of rupture, flexural beams
 - ⇒ Review contractor's proposed washout pit

DETERMINE EXACT LIMITS OF CONCRETE PAVEMENT REMOVAL

- ❑ Engineer must locate and number slabs to be removed
- ❑ Review cross sections and quantity charts in the plans to narrow down the freeway section
- ❑ Walk the freeway with the contractor, as a courtesy ask the designer and local maintenance supervisor to come along
- ❑ Look for third-stage cracking, faulting, spalling, and corner cracking
- ❑ Prepare a slab replacement log
 - ⇒ Show location and dimension of slabs to be replaced
 - ⇒ Before pre-sawing begins match the quantities of concrete to be removed on the plans with the estimate from the field review
 - ⇒ Include a column on the slab replacement log if the contract has separate pay items for dowels and/or tie bars that are placed in the slabs

PRE-SAWING SLABS

- ❑ Engineering judgment must be used when planning to pre-cut concrete slabs
 - ⇒ Review the existing condition of the slabs to determine whether the pre-cut slab will hold up under traffic until it is replaced
 - ⇒ Avoid keeping the pre-cut area open to traffic for more than 2 days, as this will cause more pavement deterioration
- ❑ Slabs may have to be cut on the night they are replaced
- ❑ Exercise caution if large traces of crack sealant are evident on the surface of the existing slabs

- ❑ Outline of concrete to be removed should be sawed full depth with a power-driven saw
- ❑ Remove the concrete in rectangular sections to simplify concrete removal
- ❑ Do not make notches or diagonal cuts in the pavement
- ❑ Water residue from concrete cutting should be vacuumed immediately

CONCRETE PAVEMENT REMOVAL

- ❑ Pavement removal should be performed without damage to pavement that is to remain in place
- ❑ Any damage to pavement that is to remain in place should be repaired to a condition satisfactory to the engineer, or the damaged pavement should be removed and replaced with new concrete pavement if ordered by the engineer

Non-impact (Liftout) Method

- ❑ Each slab should be removed in one or more sections without disturbance or damage to the underlying base or the surrounding pavement that remains in place
- ❑ Slabs can be pre-sawed prior to the night of removal and replace
- ❑ DO NOT allow the contractor to drop concrete onto the existing base when lifting out

Impact (Break-up) Method

- ❑ Caltrans does not approve any impact slab removal techniques, except for use in removal of full-depth and treated base.

Possible Problems During Removal

- ❑ Engineer determines that existing base is not suitable
 - ⇒ Base should be removed and replaced to the same thickness with new base material and covered with a bond-breaking material prior to construction of the replacement pavement; new base material should be fast-setting cement conforming to the provision of "Concrete Replacement Pavement"

- ⇒ Removal and replacement of unsuitable base material and bond breaking material will be paid as extra work, as provided in Section 4-1.03D, "Extra Work," of the Standard Specifications
- ❑ Slab is thicker than shown on the plans and pre-sawing did not reach full depth
- ❑ Water is present under the slab when concrete is removed
- ❑ Slabs shatter when lifted
- ❑ Lift pins fail to hold PCC pavement section

SLAB PREPARATION

- ❑ Contractor must provide adequate lighting

Dowel Baskets, Transverse Dowels & Tie Bars (Load Transferring Devices):

- ❑ Review Construction Details and Standard Plans to determine if dowel baskets, transverse dowels, or tie bars are required; if load-transferring devices are required, determine the spacing, depth of hole, and size of devices (Special Provisions, Project Plans, Standard Plans, and Standard Specifications)
- ❑ Headquarters (HQ) recommendations for the use of load transferring devices:
- ❑ Dowel baskets are required when replacing two or more slabs in a row on freeways carrying more than a low volume of heavy trucks
- ❑ Transverse dowels are required between new and existing slabs
- ❑ Tie bars are required if there is an unstabilized base or if placed in a region that experiences freeze-thaw cycles or receives 130+ cm of rain per year

Dowel Holes

- ❑ Dowel holes should be drilled by methods that will not shatter or damage the concrete adjacent to the holes
- ❑ Layout and depth of dowels need to be inspected
- ❑ Dowel holes should be cleaned/blown out prior to placing the epoxy

Bond Breaker

- ❑ Suitable plastic sheeting, 15 mils thick, should be placed between the replacement pavement and the base for full-depth repairs; for full-depth and treated base repairs, Suitable plastic sheeting should be placed on the subgrade or subbase layer immediately prior to concrete placement

DOWEL INSTALLATION

Transverse Contact Joints

- ❑ Expansion caps must be placed on the exposed end if a non-shrink mix is used
- ❑ Place parallel to the lane lines at a depth equal to $t/2$
- ❑ Bonding of the embedded dowel is necessary for effective load transfer

Weakened Plane Joints

- ❑ Dowels should be placed at all weakened joints within a slab repair using type A or U baskets; type J baskets do not meet the Caltrans loading requirements
- ❑ Baskets must begin at the existing pavement joint, such as the adjacent passing lane joint
 - ⇒ The joint in the new weakened plane joint should be installed perpendicular to lane lines in all situations
 - ⇒ If the joint was previously skewed, it will still be placed perpendicular to lane lines, eliminating skew within the replaced slab section.
- ❑ Each basket must be anchored securely with approved concrete fasteners (for a 3.65-m wide slab) and constructed to hold all dowels firmly at a depth of $t/2$ and maintain alignment
- ❑ Expansion caps are needed on retrofitted dowel bars.
- ❑ Once the dowels are placed and prior to concrete placement, watch for any signs of misalignment during the concrete placement; misalignment of the dowels will lead to increased stress within the new concrete pavement and result in premature cracking and failure of the repaired pavement section.

EXPANSION MATERIAL PLACEMENT

Transverse Contact Joints

- ❑ A 6-mm-thick foam expansion material must be placed securely across the transverse joint face and extend the full depth of the joint, with the top of the expansion material flush with the top of the pavement
- ❑ Expansion material must be cut to fit with holes for drill-and-bond dowels
- ❑ The expansion material should be secured to the face of the existing pavement joint by any method that will hold the expansion material securely in place during concrete placement; concrete should not be allowed to get between the expansion material and existing PCC pavement

Longitudinal Contact Joints

- ❑ Expansion materials are not required along the longitudinal contract joint for isolated pavement slab repairs
- ❑ Expansion materials may be placed along longitudinal contact joints if the adjacent pavement slabs are scheduled for replacement; use of the expansion materials prevents bonding at the longitudinal joint and will reduce slab removal and replacement times
- ❑ If expansion material is used along longitudinal contact joints, it must be placed securely across the entire length of the joint and extend the full depth, with the top of the expansion material flush with the top of the pavement joint
- ❑ The expansion materials along the longitudinal joint face must be removed when the adjacent slab is removed and replaced

CONCRETE PLACEMENT

- ❑ Ensure that slab preparation has been inspected and the contractor is permitted to place concrete

Concrete Arrives On-site

- ❑ Verify dowel alignment during placement
- ❑ Check temperature
- ❑ Watch for consistency of concrete

- ⇒ How long is the material workable?
- ⇒ How much slump does it have?
- ⇒ Other properties

- ❑ Watch for cement balls coming down the chute
- ❑ Ensure that the vibrator is keeping up with the concrete placement, especially around load transferring devices if necessary add vibrators
- ❑ Ensure that final finishing is keeping up with concrete placement, workability, surface retardant to help with finish of the concrete surface.

CONCRETE TESTING

- ❑ Concrete testing requirements are contract-specific. Some contracts require Caltrans to do the testing, whereas others require the contractor to make the arrangements
- ❑ Support Caltrans Material Tester with sampling.
- ❑ Make arrangements with testing personnel to get the test results to the Inspector, who will reopen the freeway

AFTER PLACEMENT

Curing Concrete Slabs

- ❑ Curing compound should be applied as recommended by the manufacturer of the cement and approved by the engineer in writing
- ❑ Slabs should be covered with insulating blanket
- ❑ Curing should occur in a timely manner

Protecting Newly Placed Slabs

- ❑ Completed slabs must be protected so that vehicles will not drive on them
- ❑ Contractor should have "WET CONCRETE" signs on barricades, it is recommended to place cones around the entire perimeter of the replaced slabs
- ❑ Do not place the barricades or cones on the newly placed slabs, as this will damage the surface finish

Weakened Plane Joints

- ☐ Transverse weakened plane joints in the replaced pavement should be constructed perpendicular to the direction of lane lines
- ☐ Sawing of weakened plane joints should commence as soon as the concrete will support the saw (refer to Caltrans Specification 40-1.08 B (1))
- ☐ The minimum depth of the cut for the weakened plane joint should be $t/3$, where t is the slab depth

Clean-up & Opening to Traffic

- ☐ Recommend a street sweeper
- ☐ Refresh pavement delineation, markers, and stripes
- ☐ Open freeway lanes to traffic when passing modulus of rupture test results are reported
- ☐ Concrete quantity should be agreed upon between the State and the contractor
- ☐ Quantity is based on actual measurements, not quantity on concrete tickets

GRINDING AND JOINT SEALING

Grinding and joint sealing adds life to the existing roadway by accomplishing the following:

- ☐ Remove transverse joint and crack faulting (principal function)
- ☐ Improve transverse slope
- ☐ Improve ride quality by removing faulting, surface roughness, and unevenness caused by slab replacement
- ☐ Reduce unwanted noise and provide a safe, long-lasting surface texture

Criteria for Grinding

- ☐ Faulting greater than 2.6 mm
- ☐ Most effective way is to grind an entire lane width of the roadway

Joint Sealing

- ☐ Are sawed joints established?
- ☐ Clean by water cleaning and air blasting

Sealant Installation

- ☐ Place backer rod, then place sealant
- ☐ Silicone joint sealant is to be used for all transverse and longitudinal joints when specified

MISCELLANEOUS PROBLEMS

- ☐ Test beams do not meet minimum requirements
Headquarters (HQ) recommends an OPENING TO TRAFFIC MINIMUM OF 2.4 MPa
- ☐ Engineering decision must be made if the required strength for opening is not achieved
- ☐ Contingency plans:
 - ⇒ Physically test pavement—bang with hammer, drive vehicle on it
 - ⇒ Look at the volume of traffic and buy as much time as possible; open lanes that do not need to be closed

POTENTIAL ISSUES

COLD JOINTS

- ☐ To determine if a cold joint exists, physically test the portion of concrete in place before finishing the slab—methods of testing can include hitting the concrete with a hammer, poking the concrete with a piece of rebar or standing on the concrete
- ☐ Notifying contractor's representative that a cold joint exists, and paint a reference mark on the adjacent pavement so the cold joint can be located at a later date
- ☐ Slabs may be rejected as a result of cold joints
- ☐ Key inspection items:
 - ⇒ Frequency of trucks – enough trucks must be available to deliver concrete continuously to the job site within the concrete setting time
 - ⇒ Concrete setting time
 - ⇒ Concrete temperature when discharging from ready mix truck
- ☐ Loads of concrete may be sent away by the contractor because the concrete is too hot before unloading begins; this can trigger a chain reaction for problems the rest of the shift

CONCRETE SLUMP

Low Slump

- ☐ Low slump can cause loads of concrete to be sent back/rejected
- ☐ Concrete should be delivered to the job with a slump within the approved mix design; the average is 102 to 204 mm
- ☐ Additional water (added to the surface of the concrete) should not be used because it causes problems with workability and surface finish

High Slump

- ☐ May be caused by a variety of factors
 - ⇒ Truck drivers leaving wash water in the drums of the concrete trucks
 - ⇒ Kelly ball does not measure these high slumps
- ☐ Address immediately with the grade quality control (QC) person
- ☐ Paint a reference point on adjacent pavement where you feel high slump concrete was incorporated and monitor for possible failure

CRACKING

- ☐ Thermal cracking may occur in slabs placed when the temperature hovers around 5°C; cover slabs with insulation blanket when the temperature fall below 13°C
- ☐ High slump concrete can cause cracking
 - ⇒ Surface cracks
 - ⇒ Large transverse shrinkage cracks

CLEANNESS VALUE FAILURE OF THE AGGREGATE

- ☐ If the CV is out of operating range or out of contract compliance, take corrective actions at the batch plant before the work is allowed to resume
- ☐ In accordance with Section 90-2.02 of the Standard Specifications, the State will take a deduction of \$4.60 per m³ for all concrete out of contract compliance

STRENGTH

- ☐ If 4-hour or 7-day strengths do not reach the required flexural strength, adjust pay in accordance with the contract specifications
- ☐ Test results should be graphed to look for trends in overall performance and consistency of the concrete

SAMPLING & TESTING

- ☐ At least 45 days prior to intended use, the contractor should furnish a sample of the fast-setting hydraulic cement from each lot proposed for use and all admixtures proposed for use in the quantities ordered by the engineer
- ☐ Identify the lot number of material
- ☐ Identify foreign material sources
- ☐ Samples of all components of the mix should be sent to Translab at the beginning of the job and when possible problems are detected; it is required to take random samples during the contract per Section 8 of the Construction Manual

MISCELLANEOUS

- ☐ Consistency of concrete should be noted from one batch to the next
- ☐ Temperature is critical for all components
 - ⇒ Cement
 - ⇒ Aggregate
 - ⇒ Water
 - ⇒ Admixtures
 - ⇒ Ambient air
- ☐ Ready mix concrete should be delivered by experienced drivers with specific instructions for cleaning trucks and transporting, drivers should attend JITT
- ☐ Placement methods
- ☐ Mix design criteria

SLAB REPLACEMENT LOG

[illegible]

SLAB REPLACEMENT MAP

[illegible]

Page: _____
Date: _____

CO-RTE-PM: _____

Direction: _____

Panel No.:

[illegible]

Comments:

Panel No.:

Comments:

FIELD DATA SUMMARY FORM

CO-RTE-PM:						Date:
Direction:						

Lane	Panel No.	Cracking		Faulting mm	Pumping (y/n)	Other Distress	Photo no.	Comment
		Type	Severity					

Cracking type:
 TC = transverse; LC = longitudinal; CB = corner break
 SS = Stage 3 (shattered slab with intersecting cracks)

Other distress type: ASR = Alkali-silica reactivity; R = Wheepath rutting

Distress severity: transverse cracking

	Low (L)	Medium (M)	High (H)
Crack width (mm)	< 3 mm	≥ 3 mm; < 6 mm	≥ 6 mm
Faulting (mm)	< 2 mm	≥ 2 mm; < 6 mm	≥ 6 mm
Spall width (mm)	none	< 75 mm	≥ 75 mm

Distress severity: longitudinal cracking and corner breaks

	Low (L)	Medium (M)	High (H)
Crack width (mm)	< 3 mm	≥ 3 mm; < 13 mm	≥ 13 mm
Faulting (mm)	< 2 mm	≥ 2 mm; < 13 mm	≥ 13 mm
Spall width (mm)	none	< 75 mm	≥ 75 mm

SLAB REPLACEMENT SUMMARY FORM

[illegible]

NOTES



Concrete
thermometer

Concrete testing should be performed according to established procedures, as defined by ASTM, ACI, and appropriate California Test Methods. The following provides a brief summary of the testing procedures.

TEMPERATURE TEST (ASTM C 1064)

The temperature measuring device should be capable of measuring the temperature to within $\pm 0.5^{\circ}\text{C}$ throughout the range likely to be encountered. The device should conform to the requirements for ASTM thermometer No. 36 C as prescribed in List B of ASTM E 1 or another of equal accuracy.

The temperature of the freshly mixed concrete may be taken in the transporting equipment before concrete placement in the forms, or if the sample is prepared properly, in a container following concrete placement. No matter what container is used, be sure that the sensor of the temperature measuring device has at least 75 mm of concrete surrounding it.

Gently place concrete around the temperature measuring device so that the ambient air temperature does not come into direct contact with the sensing area of the device, as this may affect the accuracy of the reading.

Leave the temperature measuring device in the freshly mixed concrete for a minimum of 2 minutes or until the temperature reading stabilizes. Then read and record the temperature of the freshly mixed concrete to the nearest 0.5°C . Complete the temperature measuring of the freshly mixed concrete within 5 minutes after obtaining the sample.

For compliance with specifications, measure the temperature of the concrete sample obtained in accordance with ASTM C 172.

SAMPLING FRESHLY MIXED CONCRETE (CT 539)

CT 539 supersedes ASTM C172.

Secure a composite sample from the middle portion of the batch as soon as possible, but in no instance should the elapsed time between obtaining the first and final portions exceed 15 minutes. Sampling can occur at the following locations:

- **Stationary mixers:** Sample the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch.
- **Paving mixers:** Sample the concrete after the contents of the paving mixer have been discharged. Obtain samples from at least five different areas of the material pile, and then combine them into one composite sample for test purposes.
- **Revolving drum truck mixer or agitators:** Sample the concrete at two or more regularly spaced intervals during discharge of middle portion of the batch.
- **Open-top trucks (mixers, agitators, non-agitating equipment, or other types of open-top containers):** Take samples using whichever procedure previously described is most applicable.

If possible, transport the sample to the location where testing will occur and specimens are to be stored.

The minimum size of sample to be used for strength tests should be 28 liters.

Combine and remix the sample.

Sample preparation:

- Begin tests for slump or air content, or both, within 5 minutes after the sampling is completed.
- Begin molding specimens for strength tests within 15 minutes after fabricating the composite sample.
- Cover sample to protect from drying.

DENSITY OF FRESH CONCRETE (CT 518)

- Determine the tare weight of the calibrated container. A 14-liter bucket is generally used for better accuracy when the concrete contains nominal 19- to 38-mm coarse aggregate.
- Remix the concrete sample, moisten the equipment, and then remove excess water.
- Fill the unit weight container in three equal layers, rodding each layer 25 times.



When rodding:

- Do not strike the bottom of the container when rodding the first lift.
- Penetrate approximately 25 mm into the previous layer.
- Tap on the sides of the container smartly 10 to 15 times with the appropriate mallet (0.568 ± 0.23 kg for measures of 14 liters or smaller) after rodding each layer.
- Vibrate the concrete when the slump is less than 25 mm. Rod or vibrate when the slump is 25 to 75 mm. Rod for slumps over 75 mm.



- There should be no substantial excess or shortage of concrete after consolidation. An excess of 3 mm is optimum. Small quantities of material can be added or removed with a scoop or trowel.
- Strike off the concrete surface by covering two-thirds of the surface with a flat 6-mm-thick metal or 13-mm-thick glass or acrylic strike-off plate. Apply downward pressure and withdraw the plate with a swinging motion to finish the original area covered.
- Cover the original two-thirds and advance the whole plate with downward pressure and a sawing motion completely across the concrete surface. Screed the surface with the inclined edge of the plate.
- Clean the sides and bottom of the container.
- Weigh the container and calculate the unit weight of the material.



AIR CONTENT OF FRESHLY MIXED CONCRETE

The air content of freshly mixed concrete can be measured using either the pressure or volumetric method. Both test methods are discussed below.



Determining Air Content of Freshly Mixed Concrete by the Pressure Method (CT 504)

- This test method is not for concrete containing lightweight or porous aggregate.
- Determine the aggregate correction factor (see ASTM C 231, paragraph 5). Remix the sample and moisten the meter.
- Moisten the equipment and then remove any excess water.

- Fill the bowl in three equal layers, uniformly rodding each layer 25 times, and penetrating 25 mm into the previous layer. Do not impact the bottom of the container while rodding the first lift. Tap the sides smartly 10 to 15 times with a standard mallet after rodding each layer. There should be no substantial excess or shortage of concrete after consolidation. An excess of 3 mm is optimum.
- Strike off excess material with a metal strike-off bar using a sawing motion. Clean the contact surfaces and dampen the rubber seal on the cover.
- Open both petcocks and clamp on the cover.
- Close the main air valve between the air chamber and the measuring bowl.
- Syringe water into one petcock until water comes out the other petcock.
- Jar the meter gently until no air bubbles come out.
- Close the air bleeder valve and pump the pressure up to the initial pressure line, as indicated on the meter (usually 2 to 3%, depending on calibration).
- Allow a few seconds for compressed air to cool and then zero the meter at the pressure line by pumping or bleeding while tapping the gauge lightly.
- Close both petcock holes on the cover.
- Open the main air valve. Sharply tap the base with a mallet and lightly tap the gauge with the hand.
- Read the air content on the gauge and subtract the aggregate correction factor.
- Release the pressure by opening both petcocks.

Determining Air Content of Freshly Mixed Concrete by the Volumetric Method (CT 543)

- Remix the concrete sample.
- Dampen the bowl and then remove excess moisture.
- Fill the bowl with concrete in three equal layers.
- Uniformly rod each layer 25 times, penetrating the previous layer approximately 15 mm. Do not impact the bottom of the bowl when rodding the first lift.
- Tap on the sides of the bowl smartly 10 to 15 times after rodding each layer.
- Strike off the excess material of the top layer with a strike-off bar using a sawing motion.
- Wipe the contact surface clean.
- Clamp the top to the base.
- Fill with water using a funnel. Remove the funnel and adjust water level to the zero mark using a syringe.
- Invert the meter and agitate until the concrete settles away from the bowl.
- Roll the meter on its flange with the neck slightly elevated for approximately 2 minutes.
- Set the meter upright, jar it lightly and wait until the air rises to the top.
- Repeat the rolling operation until no further drop in the water column is observed.
- Dispel the foam with standard measuring cups of 70% isopropyl alcohol. (It may be necessary to roll the meter several times to verify that there is no further drop in the water column.)
- The air content reading is taken at the bottom of the meniscus in the neck (estimated to the nearest 0.25%) plus the number of cups of alcohol added.

CASTING OF TEST CYLINDERS AND BEAMS

- CTM 540—Making, Handling, and Storing Concrete Compressive Test Specimens in the Field
- CTM 521—Compressive Strength of Molded Concrete Cylinders
- CTM 523—Flexural Strength of Concrete (Using Simple Beam Center-Point Loading, or Third-Point Loading)

Compressive Strength Cylinders

Note: Cylinders are shown for information only. Caltrans does not use cylinders to test strength of pavement.

- Remix the concrete sample.
- Moisten the equipment and then remove excess water.
- Fill standard 152 by 305 mm test cylinders in three equal layers.
- Distribute the concrete evenly, both when filling and when tamping, prior to consolidation.
- Rod each layer 25 times, penetrating the previous layer about 25 mm. Do not impact the bottom of the mold when rodding the first lift. Distribute the strokes uniformly over the cross section of the mold.
- After each layer is rodded, tap the outside of the mold lightly 10 to 15 times to close any holes left by rodding, and to release any large air bubbles that may have been trapped. An open hand may be used to tap light-gauge, single-use cylinder molds.



- Strike the top off with a tamping rod and float or trowel the surface.
- Clean the cylinder exterior. Mark test identification on mold.
- Cover to prevent loss of moisture.
- Initial cure for the first 24 hours must be at 16 to 27°C. Protect the sample from excess heat or cold.
- Final curing requires the concrete cylinder to be in a moist condition at $23 \pm 1.7^\circ\text{C}$ until the moment of testing.



Flexural Strength Beams- 1/3 Point Loading (CT 523)

- Remix the concrete sample.
- Moisten the equipment and then remove excess water.
- Fill the standard 152 by 152 by 508 mm beam mold. This mold is used for concrete with nominal maximum-sized coarse aggregate up to 50 mm in two equal layers.
- Distribute the concrete evenly within the mold, both when filling and when tamping, prior to consolidation.

Rodding: Rod each layer once for each 1300 mm^2 of top surface area of the specimen. Distribute the strokes uniformly over the cross-section of the mold. Rod the bottom layer throughout its depth. When rodding the upper layer, allow the rod to penetrate about 15 mm into the underlying layer when the layer is less than 100 mm deep. Penetrate 25 mm when the layer is 100 mm deep or more.

Vibration: After each layer is vibrated, tap the outside of the mold to close any holes left by vibrating, and to release any large air bubbles that may have been trapped.

- After each layer is rodded, spade the concrete along the sides and end of the beam molds with a trowel or other suitable tool.
- When placing the final layer, avoid overfilling the mold by more than 5 mm.
- Strike off the surface of the concrete and float or trowel as required. Perform all finishing with the least manipulation necessary to produce a flat, even surface that is level with the edge or rim of the mold.
- Cover the specimens immediately after finishing to prevent moisture loss.
- The 24-hour initial cure must be moist at $23 \pm 1.7^\circ\text{C}$ until the moment of the test.

RECOMMENDATION FOR RSC:

- Consider plastic molds to retard heat loss.
- Perform flexural strength testing as soon as needed for opening slab to traffic



BALL PENETRATION TEST IN FRESH PORTLAND CEMENT CONCRETE (CT 533)

The ball penetration apparatus consists of a 152-mm cylinder (the “Kelley Ball”) with a hemispherical bottom that is machined to a smooth finish.



- The test may be made on concrete in a wheelbarrow, buggy, other container, or after the concrete has been deposited. The concrete depth shall be at least 150 mm for 25-mm or smaller maximum size aggregate. Use 200 mm depth for larger aggregate.
- Strike off the concrete surface over an area of about 0.30 m². Do not tamp, vibrate, or consolidate the concrete. Screed the minimum amount required to obtain a reasonable level surface. Overworking may flush excess mortar to the surface and cause erroneously high penetration readings.
- Hold the device by the handle and lower it slowly over the prepared area until the feet of the yoke touch the concrete surface. Make certain that the shaft is vertical and free to slide through the yoke. Gradually lower the ball onto the concrete, maintaining enough restraint on the handle so that penetration is due to the dead load of the ball only

and not to any force generated by acceleration of the mass.

- When the ball comes to a rest, release the handle and read the penetration to the nearest 5 mm. Penetration of the feet of more than 3 mm may indicate that the concrete has been overworked, or that the yoke is binding on the shaft.
- Take a minimum of three readings for each penetration determination. Individual readings shall be at least 250 mm between centers. The minimum horizontal distance from the centerline of the handle to the nearest edge of the level surface on which the test is made shall be 150 mm.
- Report the average of the first three successive readings that agree within 15 mm of penetration.

The amount of water used in concrete mix shall be regulated so that the consistency of the concrete as determined by the penetration test (CT533) is within the following range:

- Nominal penetration: 0 to 25 mm
- Maximum penetration: 40 mm

When Type F or Type G chemical admixtures are used, the measurements must be taken prior to the addition of those admixtures.

NOTES

APPENDIX C EMERGENCY SLAB REPLACEMENT

Occasionally, a situation may require immediate unscheduled repair due to premature pavement failures, blow-ups, or excessive reflective cracking in a crack and seat asphalt overlay.

Blow-ups are typically caused by high temperature and incompressibles in the transverse joints. Hot temperatures cause the panels to expand and result in increased pavement stresses. Debris in the transverse joints, such as small rocks, or dirt, causes additional stress as the panels are pushed up against each other. With no place to move, the slabs eventually either "walk up" at one end or "blow out" at mid-panel from the increased stress. Older panels that were approximately 6m long contributed to this type of failure.

Excessive reflective cracking in crack and seat overlays can also lead to premature failure. This is primarily due to the loss of uniform support coupled with the slab's inability to carry the actual traffic loads. Conditions like these can lead to excessive reflection cracking of asphalt overlay.

Many times the repair option for these premature failures is limited to removing the slab and filling the hole with asphalt concrete. An asphalt concrete repair is typically selected due to the need to get traffic back on the pavement with the least possible disruption to traffic flow. However the disadvantages to this kind of strategy are:

- Achieving adequate compaction in a confined space, especially adjacent to the old existing concrete that will remain in place.
- Getting hot mix asphalt to quickly cool at a depth of 0.3 m.

In addition, such a repair strategy can further contribute to the deterioration rate of adjacent slabs by allowing excessive movement of the adjacent slab joints during routine traffic loading, large temperature

changes, and freeze thaw cycles. Asphalt repairs in JPCP significantly reduce the aggregate interlock needed for load transfer. Reduced aggregate interlock results in higher stresses at the edges of the PCC pavement, adjacent to the AC patch, causing premature failure of the concrete and excessive faulting and roughness of the pavement surface.

The preferred repair option is to place RSC. Always consider the remaining life of the pavement when selecting the repair type, as well as the repair material. The use of RSC and load transfer devices will reduce the edge stresses in the older concrete slabs, as well as the repaired area, resulting in a better long-term performance solution. If the construction window does not permit the use of RSC, use an AR-8,000 or AR-16,000 asphalt binder to stiffen the mix. Remember that asphalt concrete is a short-term slab repair strategy.

When using RSC to repair deteriorated AC over crack and seated concrete, use Lampblack in the mix. This darkens the concrete to be more aesthetically pleasing in areas with asphalt overlays. Remember to mark the location on the shoulder with a paddle identifying the PCC plug so that future jobs, especially recycling projects, are aware that there is PCC in this location.

Remember that emergency repairs with RSC need not be temporary in nature. With ever-increasing traffic-control and user costs, especially on heavily traveled freeways, RSC may very well be the most cost effective and longer lasting solution.

In emergency, there will likely be a short construction window, and it is recommended in all cases to cover RSC with plastic and plywood to insulate and speed cure.

NOTES

APPENDIX D LIST OF ACRONYMS

- AC – Asphalt Concrete
- ACPA – American Concrete Paving Association
- ASR – Alkali-Silica Reactivity
- ASTM – American Society for Testing and Materials
- CTB – Cement Treated Base
- CT – California Test
- CV – Cleanness Value
- CTM – California Test Method
- FWD – Falling Weight Deflectometer
- HQ – Headquarters
- JPCP – Jointed Plain Concrete Pavement
- LTE – Load Transfer Efficiency
- METS – Material Engineering and Testing Services
- NDT – Nondestructive Testing
- PCC – Portland Cement Concrete
- PCCP – Portland Cement Concrete Pavement
- QC – Quality Control
- RSC – Rapid Strength Concrete
- SSP – Standard Special Provisions

NOTES

APPENDIX E APPLICABLE STANDARDS

STANDARD SPECIFICATIONS

- ☐ Section 25: Aggregate Subbase
- ☐ Section 28: Lean Concrete Base
- ☐ Section 40: Portland Cement Concrete Pavement
- ☐ Section 42: Groove and Grind Pavement
- ☐ Section 68: Subsurface Drains
- ☐ Section 90: Portland Cement Concrete

STANDARD PLANS

- ☐ A35A: Portland Cement Concrete Pavement (Undoweled Transverse Joint)
- ☐ A35B: Portland Cement Concrete Pavement (Doweled Transverse Joint)
- ☐ A35C: Portland Cement Concrete Pavement Joint and End Anchor Details
- ☐ A35D: Dowel Bar Retrofit in Existing Concrete Pavement

STANDARD SPECIAL PROVISIONS

- ☐ SSP 40-010: Concrete Pavement (with Doweled Transverse Weakened Plane Joints)
- ☐ SSP 40-015: Retrofit Existing Concrete Pavement with Dowels at Transverse Joints
- ☐ SSP 40-020: Replace Concrete Pavement (Rapid Strength Concrete)
- ☐ SSP 40-030: Portland Cement Concrete Base
- ☐ SSP 41-150: Repair Spalled Joints
- ☐ SSP 41-151: Repair Spalled Joints (Polyester Grout)
- ☐ SSP 41-200: Seal Joint

NOTES